EXTRACT

FROM THE ANNUAL REPORT OF THE

MEDICAL OFFICER

OF

THE LOCAL GOVERNMENT BOARD

For 1908-09.

REPORT ON

INVESTIGATIONS IN THE PUBLIC HEALTH LABORATORY OF THE UNIVERSITY OF MANCHESTER UPON THE PREVALENCE AND SOURCES OF TUBERCLE BACILLI IN COWS' MILK;

BY

SHERIDAN A. DELÉPINE

(*Director of the Public Health Laboratory and Professor of Comparative Pathology and Bacteriology, University of Manchester*).

LONDON:
PRINTED FOR HIS MAJESTY'S STATIONERY OFFICE,
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Extract from the Annual Report of the Medical Officer of The Local Government Board for 1908-09.—Report to the Local Government Board on Investigations in the Public Health Laboratory of the University of Manchester upon the Prevalence and Sources of Tubercle Bacilli in Cows' Milk; by Sheridan A. Delépine (Director of the Public Health Laboratory and Professor of Comparative Pathology and Bacteriology, University of Manchester).

Synopsis.

(15599r—Mis.) Wt. L 331—1,2,10. 200. 2/10. D & S. A 2

INTRODUCTION.

THIS report deals with experiments conducted privately by me between 1892 and 1908, and with official work carried out in my laboratory between the years 1896 and 1908 for the Public Health Departments of Manchester, Salford, Liverpool, Sheffield, Derby, Bristol, Blackburn, Blackpool, Burton-on-Trent, and a few other places.

It is, however, chiefly concerned with the work done for the Manchester Authority. This work was of considerable magnitude as compared with that done for all the other authorities, and the attempt made by the Manchester Sanitary Authority towards the purification of the town milk supply is probably the most important and successful of its kind.

Whatever value this report may have is in great part due to the readiness with which the medical officers of health and the veterinary surgeons engaged in the work have supplied me at all times with the information and material which I needed in the course of my investigations.

To Dr. Niven and his able assistants I am specially indebted in that respect. It will also be observed that but for the public spirited interest which the Manchester Sanitary Committee have taken in the milk question, the records upon which this report is based would have been considerably reduced.

The report was prepared in pursuance of an instruction from the Local Government Board (June 4th, 1908) asking me to present the result of my investigations on the prevalence and sources of tubercle bacilli in cows' milk. It is in great part based upon observations and experiments made in the Public Health Laboratory of the University of Manchester, in connection with the examination of 7,000 samples of milk.

A discussion of the relations between human and bovine tuberculosis, or of the share taken by cows' milk in the production of tuberculosis in man, would therefore be out of place in this statement, which, for the same reasons, cannot be burdened with the literature of the subject.

When I took up this investigation in 1892 very little was known regarding the prevalence of tubercle bacilli in cows' milk and the value of methods of detection. In dealing with the work done in my laboratory between 1892 and 1908 I therefore have, *firstly*, to discuss the experimental work which led me to adopt certain methods for the detection of tubercle bacilli in cows' milk; and, *secondly*, to deal with the results obtained by the use of these methods in connection with the administrative work of sanitary authorities. With the exception of Diagram III., which I have prepared from data obtained in Aberdeen, all the tables, diagrams and maps are based upon my own observations; the photographs of organs have been taken from dissections prepared by myself.

PART I.

I.—Methods used for the Detection of Tubercle Bacilli.

The presence of tubercle bacilli in tuberculous products may be ascertained by three methods:—

1. The microscopical method.
2. The cultivation method.
3. The inoculation or experimental method.

The cultivation method is uncertain, more especially when tubercle bacilli are associated with other organisms.

The microscopical and the inoculation methods are at present the only ones suitable for serial work.

A.—*Microscopical method.*

In cases of advanced tuberculosis of the udder, the bacilli may be so abundant in the secretion that their presence can easily be demonstrated in the minutest drop of that fluid. When disease of the udder is less advanced the bacilli may be so scanty and unequally distributed that many drops of milk have to be examined before a few bacilli are found.

When the tuberculous milk of one cow is mixed with the milk of many cows, as is usually the case with the milk supplied to the consumer, the detection of tubercle bacilli by the direct examination of the milk is frequently so difficult as to be impracticable.

When milk is centrifugalised in tubes, a large proportion of the bacilli are thrown to the bottom of the tube with the cells and extraneous products, or carried by the cream towards the opening of the tube. *They are therefore much more abundant in the sediment and in the cream* than in an equal quantity of the unseparated milk. The sediment is more suitable for microscopical examination than the cream. In milk containing a fair number of tubercle bacilli it is

comparatively easy to demonstrate their presence by preparing films with part of the sediment, and staining these films according to the method described (at page 376) in Part II. of this report. Bacilli may, however, be numerous enough to cause infection and yet too scanty to be found in every drop of sediment examined. The sediment obtainable from 40 cc. (1⅗ ozs.) of *mixed milk* (including the milk of a diseased udder) frequently measures 40 to 60 cubic millimetres. It is difficult to examine under the microscope in a single preparation more than one or two cubic millimetres of sediment. If there were only two bacilli in the sediment of 40 cc. of milk it would often be necessary to examine at least 10 to 15 preparations before one of these bacilli was discovered. The preparation and examination of each film would take, on an average, from 20 to 30 minutes. In some cases nearly the whole sediment would have to be examined before the bacilli were found. If no bacillus was found in the sediment of one ounce of milk this would be no proof that no bacilli could be found in another ounce. In routine work it is impracticable to devote so much time to the examination of one sample of milk, and it is usual to examine only one or two films. The presence of 10 to 15 bacilli (in 40 cc. of milk) may therefore be easily overlooked. It is not unusual for a tuberculous cow to yield eight quarts of milk a day, and I have known cases in which the quantity reached 18 quarts. A tuberculous cow might therefore produce milk containing daily from 3,200 to 10,800 bacilli without these being certainly detected by the microscopical method. But as the bacilli are not equally distributed in the milk, and are often in small groups of 5, 10, 20 or more, a much greater number may escape notice than the above calculations would lead one to believe.

Various methods have been proposed with the object of obtaining a greater concentration of the bacilli than can be obtained by simple centrifugalisation, but in my experience these methods have not proved serviceable.

The microscopical method cannot be relied upon for the examination of mixed milk, but, by adopting certain devices, described at page 375 in Part II. it is capable of yielding useful results in connection with the examination of the unmixed milk of single cows.

B.—*Inoculation method.*

The inadequacy of the microscopical method led me to study in 1892 how the more delicate inoculation method could be used in routine work for the detection of tubercle bacilli.

I inoculated various kinds of animals in different parts of the body with several kinds of tuberculous and other products, and with various quantities of pure cultures of tubercle bacilli and I came to the conclusion that, for the purpose I had in view, guinea-pigs were the most suitable animals. Subcutaneous inoculation on the inner aspect of the hind leg at the level of the knee with matter containing an extremely small number of bacilli produces rapidly in the guinea-pig typical lesions, the extent and distribution of which are of great value in determining the degree of virulence of, or number of bacilli in, the products. Subcutaneous inoculations in other parts of the body, or intraperitoneal injections yield much less definite or comparable results.

The results of experimental inoculation of two guinea-pigs killed respectively 19 days and 111 days after inoculation with tuberculous products of moderate virulence are shown in Figs. 1, 2 and 3. Both animals had been inoculated on the inner aspect of the left leg at the level of the knee, care being taken to inject the material under

FIG. 1.

Guinea pig inoculated subcutaneously on the inner aspect of the left leg at the place indicated by a pin. Killed 19 days after inoculation. Popliteal, left superficial and deep inguinal glands, and (to a slight extent) sublumbar glands on the left side of the body enlarged and tubercuIous. The corresponding glands on the right side were normal.

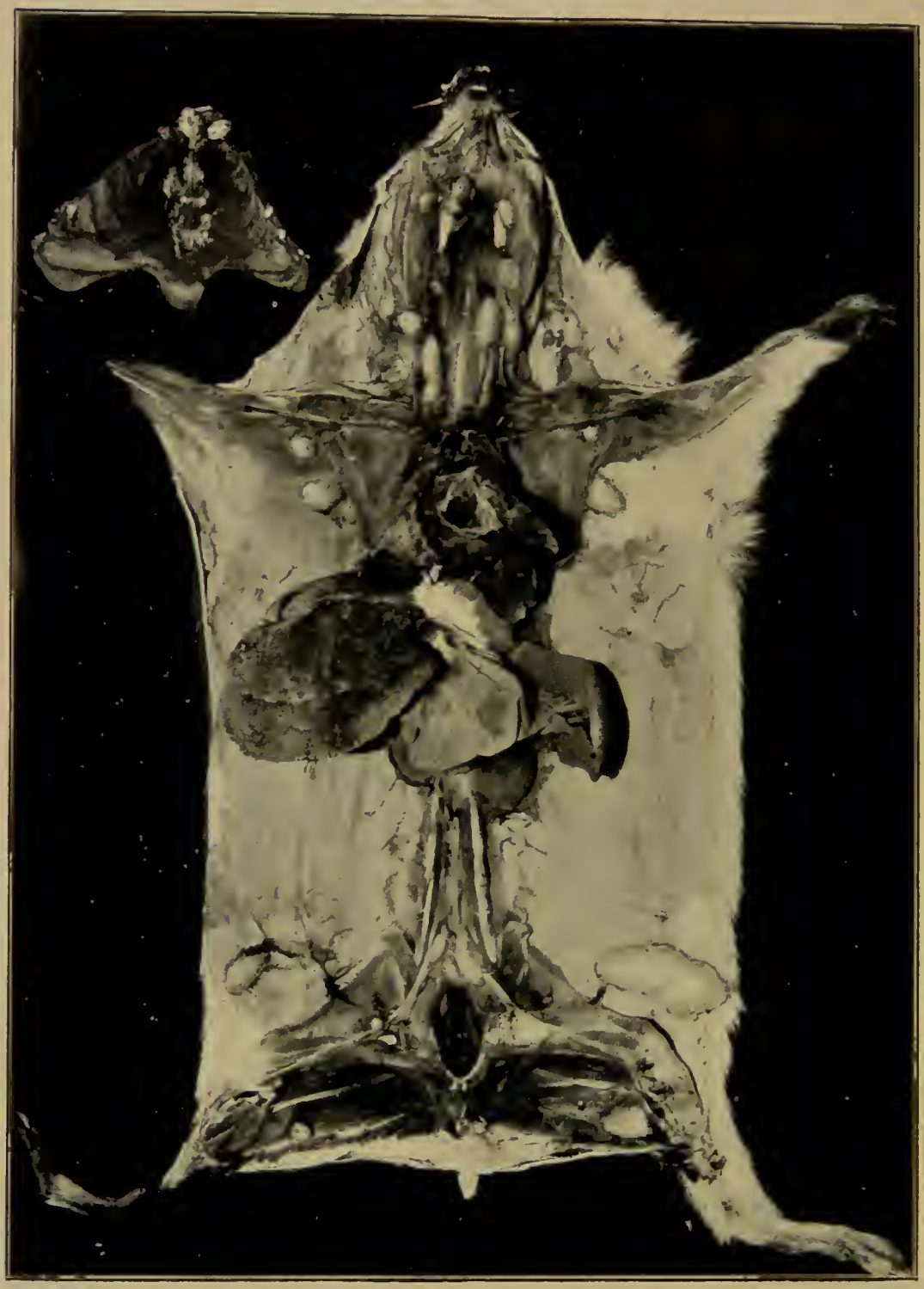


FIG. 2.

Guinea pig inoculated subcutaneously on the inner aspect of the left leg, at the same level as the guinea pig represented in Fig. 1. Killed 111 days after inoculation. All the lymphatic glands exposed by the dissection on both sides of the body are tuberculous, those connected with the left leg (seat of inoculation) are much larger and in a more advanced state of caseation and fibrosis than those connected with the right leg.

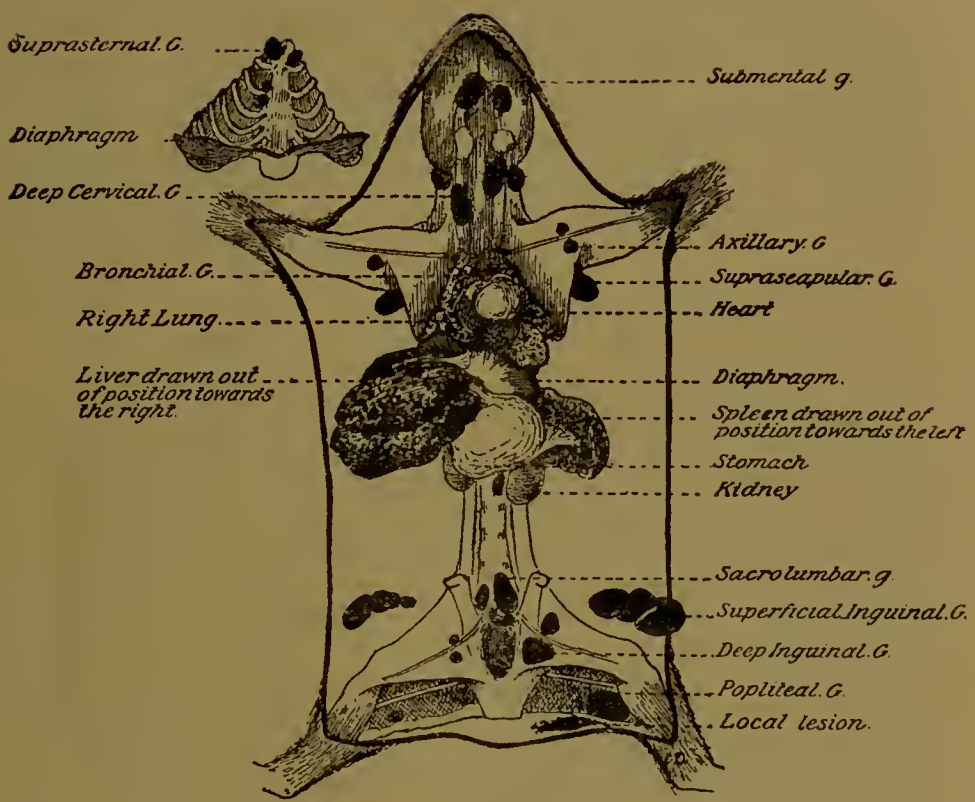


FIG. 3.

Diagram of dissected guinea pig represented in Fig. 2.
The tuberculous glands and tuberculous lesions in the viscera are printed black

To face fig. 2.

the skin, without injuring the subjacent muscles. In the first guinea-pig (Fig. 1) the lesions are limited to the subcutaneous tissue and four groups of lymphatic glands (the popliteal, superficial, inguinal, deep inguinal and sacro-lumbar) on the same side of the body as the seat of inoculation. In the second guinea-pig (Fig. 2) all the lymphatic glands exposed by dissection are distinctly tuberculous, not only those in the neighbourhood of the seat of inoculation, *i.e.*, on the left side of the body and behind the diaphragm, but also those in the thorax, neck, head and fore limbs on both sides of the body, and the popliteal, inguinal and sacro-lumbar glands on the right side of the body. In Fig. 3, which is a diagrammatic key to the photograph of the second guinea-pig (Fig. 2), all the tuberculous glands have been painted black, as well as the tuberculous lesions of the lungs, liver and spleen. The names of the most important lymphatic ganglia or groups of ganglia are also given in that diagram.

On the basis of some 90 preliminary experiments I came to the conclusion that when guinea-pigs are inoculated with minute quantity of pure cultures of tubercle bacilli, or of tuberculous products, according to the method previously described, the spread of infection follows almost invariably a very definite course from which it is possible to estimate fairly accurately the degree of infectiousness of the products used for inoculation.

C.—*Estimation of the virulence of tuberculous products, degrees of experimental tuberculous infection.*

To obtain standards suitable for comparison purposes I inoculated a number of guinea-pigs weighing from 7 to 8 ounces according to the method described in the preceding section.

For this purpose I used blood serum pure cultures of tubercle bacilli recently isolated from human tuberculous sputum. The quantity inoculated was in every case a little less than $\frac{1}{20}$ of a milligramme (gramme 0·00005). The guinea-pigs were killed at various intervals after inoculation, then dissected and all the lesions visible to the naked eye noted. These lesions were all examined microscopically and only those in which tubercle bacilli could be demonstrated were regarded as certainly tuberculous. In another series of experiments I tested by inoculation the state of all the glands and organs of the body, and found that many were invaded by tubercle bacilli several days before definite lesions were recognisable to the naked eye. (These early stages of invasion cannot be conveniently utilised for diagnostic purposes.) Lesions recognisable by the naked eye were found to occur in various tissues or organs in the following order. (The position and names of each gland are given in Fig. 3.)

First week.—Subcutaneous tissue at seat of inoculation, adjacent popliteal gland.

Second week.—Superficial and deep inguinal glands, sacro-lumbar glands, retrohepatic gland, spleen (*i.e.*, all the lymphatic glands behind the diaphragm on the inoculated side the retrohepatic gland, and the spleen).

Third week.—Liver, bronchial glands, lungs (the lung lesions are often indistinct).

Fourth week.—Lungs (distinctly), suprascapular, deep and superficial cervical glands (*i.e.*, the lymphatic glands in front of the diaphragm, on both sides of the body, the axillary and cubital glands are however seldom clearly affected at that stage).

Fifth and following weeks.—The invasion of the lymphatic glands in front of the diaphragm becomes more complete and the

lymphatie glands behind the diaphragm and on the *side not inoculated* beeome gradually affeeted beginning with the superficial inguinal gland.

As lesions appear in new organs, the older lesions increase in extent, passing through stages of necrosis, caseation, fibrosis, &c. At first the organs affeeted increase eonsiderably in size, but after a time they show a tendeney to eontraetion owing to the produetion of fibrous tissue and absorption of degenerated produets.

When the quantity of tubercle baeilli is increased it is usually found that the rate of invasion is more rapid and the lesions more extensive. This however is not always the case, and baeilli which have been eultivated for many generations outside the body often lose their virulenee more or less completely although they eontinue to grow luxuriantly. The same differenees are observed in morbid produets, the infeetivity of whieh is not always proportional to the number of baeilli demonstrable by the mieroscopieal method nor distinctly related to their souree. (The Value of Experimental Tubereulosis in Diagnosis, "British Medieal Journal," 1893.)

The extent and distribution of the tubereulous lesions in an inoeulated animal are determined by six faetors :—

1. The number of baeilli.
2. The virulence of the bacilli.
3. The time whieh has elapsed sinee infection.
4. The resistanee of the animal to infeetion.
5. The seat of inoeulation and
6. The amount of damage done to the tissues at the time of inoeulation.

For purposes of eomparison some of these factors may be more or less suceessfully redueed to eonstants by suitable preeautions. The differences produeed by time ean be eliminated by examining the animals after a constant interval of time.

The resistanee of the animal ean be made as eonstant as possible, by using animals of the same race, age and weight, and keeping them previous to, and after, inoeulation under identieal conditions. It is obvious that in praetiee one is obliged to be satisfied with eonditions which are only approximately similar. The seat of inoeulation and the amount of damage done to the tissues ean be made practieally constant by due attention to details.

The only two faetors whieh are necessarily variable are the number of baeilli and their virulenee.

When one has to deal with pure cultures of tuberele baeilli it is fairly easy to estimate the number by eounting the baeilli in an aliquot part of a weighable quantity of eulture. Whatever care is taken only rough estimates of numbers ean be obtained. The number of baeilli being approximately known it is then possible to estimate roughly their virulence.

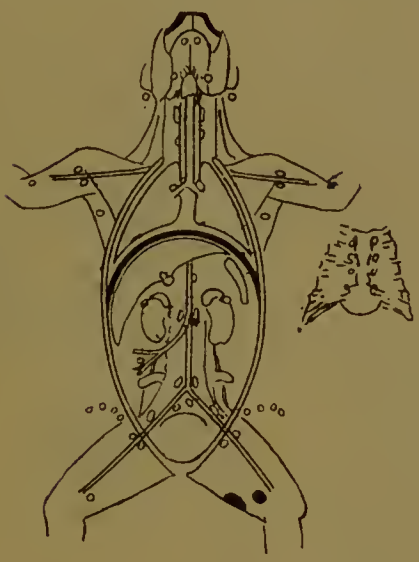
With regard to morbid products the estimation of the number of bacilli presents great diffieulties, and the figures obtained are liable to eonsiderable and unavoidable errors.

If the virulence of tuberculous produets or of cultures of tubercle bacilli obtained from the same organs in the same kind of animals was eonstant, the quantity of baeilli eould be readily estimated by the effects produeed by the inoeulation of equal amounts of material. Known facts do not, however, support the view that tubercle bacilli obtained from the same organ of the same kind of animal have a constant virulenee, and this supposition eannot be aceepted as a basis of eomparison between individual cases.

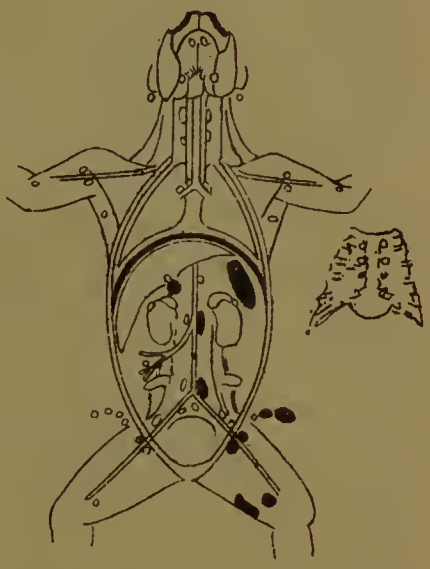
When, however, the average results of a set of several hundred inoculations, made with equal quantities of the same kind of tuber-

Fig. IV.

4 Guinea Pigs inoculated with equal small quantities of Tuberculous matter on the inner aspects of the left leg at the level of the knee. To show diagrammatically the 4 most characteristic stages or degrees of Tuberculous Infection. For names of parts see Fig 3. (Tuberculous lesions, black.)



1st Degree.



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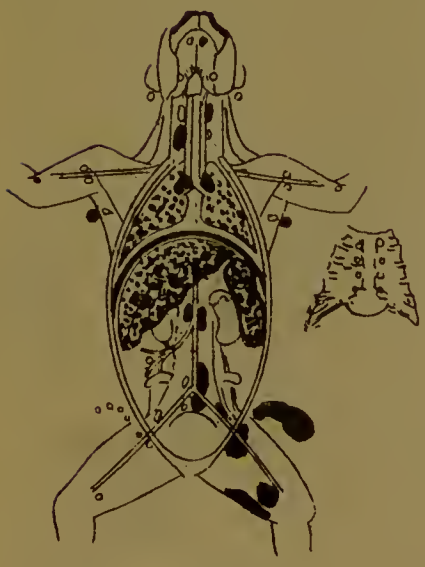

3rd Degree.

4th Degree.

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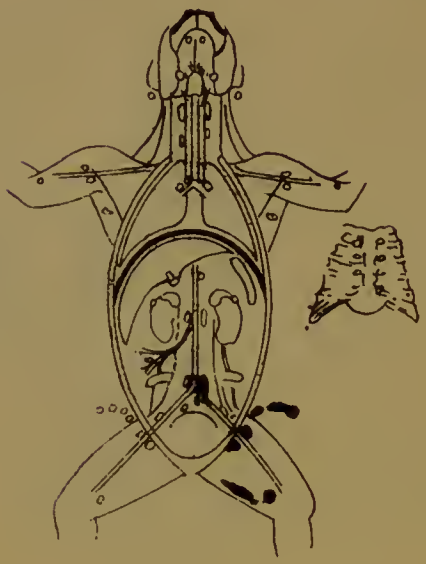
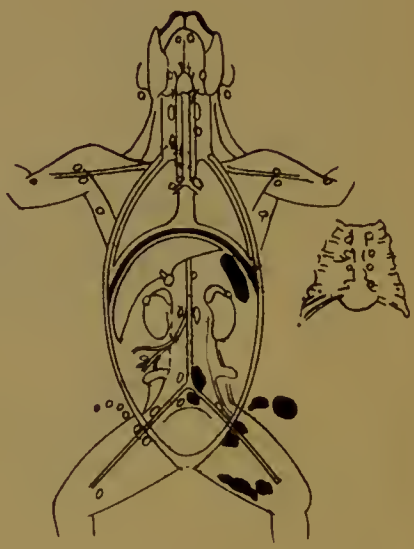
Fig V.

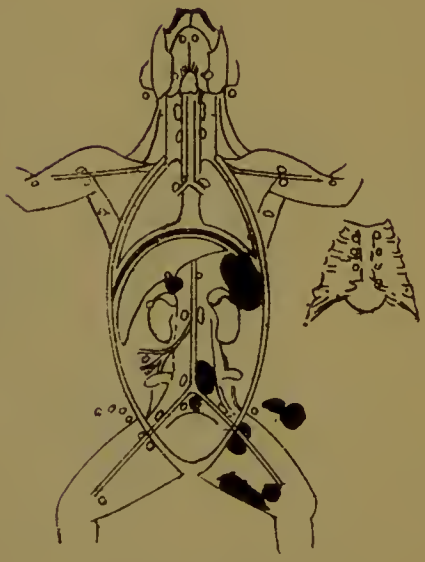
Tuberculous lesions produced in 15 days in 4 Guinea pigs inoculated with various quantities of the same milk on the inner aspect of the left hind leg at the level of the knee. (Tuberculous lesions, black.) For names of the organs, see Fig. 3.



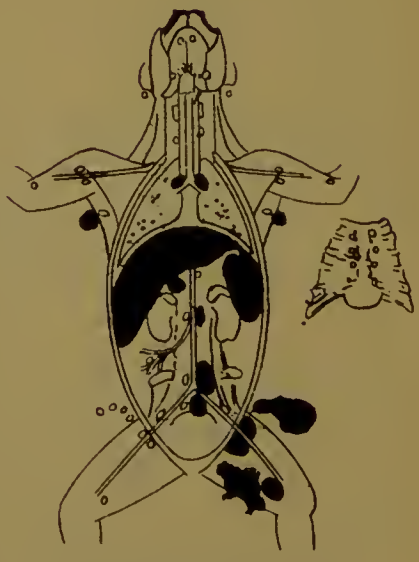
A. 0·0002 GRAMME.



B. 0·002 GRAMME.



C. 0·02 GRAMME.



D. 0·2 GRAMME.

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culous product are compared with those of another set of inoculations made under the same conditions, it is reasonable to assume that, all the other factors being the same, the differences between the average results will in all probability be due to differences in the number of tubercle bacilli.

With the object of simplifying records and making comparisons easier I have subdivided the development of experimental tuberculous lesions in the guinea-pig into four stages which are determined by the number and situation of tuberculous lesions *visible to the naked eye.* These stages are indicated by the lesions produced in a certain length of time by subcutaneous injection of $\frac{1}{200}$th of a milligramme of a pure culture of tubercle bacilli of moderate virulence into the inner aspect of *the left leg* at the level of the femoro-tibial articulation. (*See* Fig. 4.)

Stage or Degree.	Time after Inoculation.	Organs affected with Lesions visible in an ordinary Dissection.
1	Within 10 days ...	Subcutaneous tissue at seat of inoculation, adjacent popliteal gland in left leg.
2	10 to 20 days ...	A.—*Left ;* superficial and deep inguinal glands. Sacro-lumbar glands. B.—Retrohepatic gland and spleen.
3	20 to 35 days ...	Liver, lungs, bronchial glands, suprascapular glands, cervical glands on both sides of the body.
4	35 days and after ...	More complete invasion of the lymphatic glands in front of the diaphragm on both sides of the body. *Right*—superficial and deep inguinal glands and other glands behind the diaphragm on the right side of the body.

It is obvious that the number of stages could be considerably increased, and that this would allow of the time periods being made more definite ; four stages seem, however, sufficient for general purposes of comparison. It might, however, be advantageous to divide the second stage into two sub-stages indicated by the letters A and B in the above table.

I have previously stated that the extent of the lesions is influenced both by time and by the number of bacilli in the material inoculated. To ascertain the influence of the number of bacilli I inoculated four guinea-pigs with the sediment of equal quantities of various dilutions of a sample of milk obtained from a cow with advanced tuberculosis of the udder. At the end of 15 days I killed these four guinea-pigs and found tuberculous lesions in each. There was a distinct relation between the amount of the tuberculous milk (and, therefore, of tubercle bacilli) and the extent of the lesions as is shown by the following table and by Fig. 5.

Dilution.	Quantity of Original Milk contained in the Material inoculated.	Approximate Number of Tubercle Bacilli.	Degree of Tuberculosis observed at the end of 15 days.
	cc.		
$\frac{1}{10000}$	0·0002	At least 30 ...	2nd A. lesions small.
$\frac{1}{1000}$	0·002	„ 300 ...	2nd A. to B.
$\frac{1}{100}$	0·02	„ 3,000 ...	2nd B.
$\frac{1}{10}$	0·2	„ 30,000 ...	3rd lesions larger.

The differences though well marked at the end of 15 days would have been more marked if the animals had been kept three weeks instead of two. It would appear that the number of bacilli has a greater influence on the size of the lesions than on the spread of infection. Time has a greater influence on the spread.

D.—*Quantity of material used in experimental inoculation.*

The quantity of fluid injected under the skin of the leg at the level of the knee is not immaterial, too great a quantity of fluid injected rapidly causes mechanical lesions followed by more or less extensive necrosis or degeneration of tissues. On the other hand when a large quantity of fluid is injected slowly, the fluid infiltrates the tissues to a considerable distance from the seat of inoculation and the advantages of a clearly defined primary lesion are lost.

I found experimentally that the amount of fluid that can safely be injected in the selected region should not exceed 2 cc.

The injection of 2 cc. of normal milk does not appear to produce any material local or general disturbance of the health of the guinea-pig.

In testing milk for the presence of tubercle bacilli I use for inoculating each animal the sediment of 40 cc. (a little less than $1\frac{1}{2}$ oz.) which is a smaller amount than that taken by a child daily. This amount corresponds to about one-fifth of the weight of the experimental animal. I have found that the administration to kittens, by the mouth of an amount of tuberculous cow's milk bearing to the body weight the same proportion, was generally followed by tuberculosis, even when only one dose of the milk was administered. This does not necessarily prove that a child would be infected by a proportional amount of milk, but the danger of infection must for the present be assumed. The question of the communicability of bovine tuberculosis to man is not discussed in this report.

As two guinea-pigs are inoculated with each sample of milk, the total amount of milk tested is 80 cc. (*i.e.*, less than 3 oz.). This quantity of milk is much smaller than that taken in 24 hours by an infant. If this amount of milk is found to contain virulent tubercle bacilli, danger to the child must be assumed.

E.—*Precautions necessary to avoid accidental infections.*

No other bacteria than those present in the udder and a few of those present on the teat should find access to the unmixed milk obtained from individual cows. When samples of this kind are taken the udder and teat should be clean and the veterinary inspector should milk the cow directly into a sterilized bottle.

With regard to the mixed milk sent to towns, it is obvious that it is the state of the milk contained in the milk cans that has to be investigated. This milk has been exposed to various sources of contamination at the farm and in transit. A sample taken at the railway station is, therefore, invariably contaminated, but care should be taken by the inspector not to add to the contaminations already present, and he must, therefore, collect the milk with the strict aseptic precautions which are detailed in the second part of this report (page 372). It is only by the exercise of great care in the collection of samples, that erroneous conclusions and serious administrative difficulties can be avoided.

With the object of preventing accidental infection all the inoculations should be performed so as to secure complete asepsis, and

after the animals have been inoculated they should be isolated in sterilized cages, frequently cleaned. The food and water should be of good quality and clean. Accidental tuberculous infection, *i.e.*, infection not due to the presence of tubercle bacilli in the sample itself, should not occur when these precautions are taken.

Other infections than the tuberculous may however occur at times, some of these are avoidable, others are not.

Mixed cows' milk as sent to towns is almost invariably contaminated with fæcal bacteria, and if the milk is kept too long at ordinary temperature these bacteria frequently multiply to such an extent as to be capable of producing more or less severe local or general infection of inoculated animals. Among the lesions so produced the following are the most important : extensive local abscesses, extensive necrosis and ulceration, general septic infection, with peritonitis, pleurisy, pericarditis, œdema and hæmorrhage, pyæmia. A more chronic infection resembling chronic pyæmia sometimes occurs, it has been described as pseudo-tuberculosis although its resemblance to tuberculosis is superficial. It is not unfrequently also produced by intestinal infection due to the use of contaminated food. Some of these infections are so rapidly fatal that tuberculous lesions have no time to develop. During the year 1896 when I received, often from considerable distances, and during the summer, samples of milk which had not been suitably treated, about 20 per cent. of the samples of mixed milk gave rise to one or other of these complications. If the milk is refrigerated (when it has to be kept for more than 5 or 6 hours) these accidental infections rarely occur in more than 1 per cent of the cases. The methods which I have adopted to prevent these accidents are described in Part II. (pages 372 and 374).

F.—*Complications due to unavoidable concomitant infection.*

There are, however, *some forms of infection which are unavoidable*, and which may interfere with the inoculation test for tuberculosis. Concomitant infections capable of interfering with the development of tuberculosis occur extremely rarely. Among the few cases which I have specially noticed there are two of special interest. In these cases the streptococcus pyogenes was associated with the bacillus tuberculosis in the original material. Mixed suppurative and tuberculous lesions were produced, and the pus obtained from the abscesses during the life of the inoculated animal contained, side by side, the streptococcus and the bacillus. The animals recovered and when they were killed a few weeks later, no trace of tuberculous lesions could be discovered. It is therefore possible that in some cases of mixed infection the animals may recover from an early tuberculous infection and that the presence of tubercle bacilli may escape notice. Such cases are certainly of extreme rarity, more specially when the animals are examined three weeks after inoculation as is my practice.

II.—The Cow's Udder.

The udder is situated between the two thighs, and its posterior narrower part is immediately below the anus, vulva and urethra, most of its parts are accessible to the tuft of the tail when the tail is swished. In addition to the usual 4 teats, sometimes there are 2 supernumerary teats. The skin over the udder is hairy, except where it covers the teats.

The organ is composed of two halves separated by a median septum (Figs. 6 and 7), each half having a teat on each of its two quarters.

There is no distinct septum between the anterior and posterior quarters; nevertheless each quarter discharges its secretion through the corresponding teat, and one quarter may be diseased without the other quarter on the same side being affected.

The consistency of the udder varies according as the organ is full of milk or empty. When the organ is distended with milk it feels uniformly tense. When empty it feels uniformly soft, and the skin can be pushed deeply between the two halves or between the wall of the abdomen and the gland. When the udder is diseased certain of its parts may be enlarged or indurated, and these changes can usually be recognised by inspection and palpation *when the udder is empty.* There is one lymphatic gland at the posterior end of each half of the udder close to its attachment to the abdominal wall and to the inner aspect of the thigh. These glands are soft and difficult to recognise by palpation when they are normal, but when diseased they often reach a large size and may then be felt through the skin.

The glandular substance of a healthy udder between the periods of lactation has a pale greyish red colour and is almost opaque. During lactation a large number of small creamy white round or elongated or branched patches are more or less equally distributed through the substance of the organ. These spots are produced by the accumulation of milk in the acini or intralobular ducts (*see* Fig. 10 facing page 356). The intralobular ducts open into larger ducts known as lactiferous ducts which converge towards the base of the teat where they unite to form an elongated cavity continuous with a longer cavity occupying the whole length of the teat. This cavity is known as the *galactophorus sinus* or *cistern.* The cistern is emptied through a short straight tube known as the *duct of the teat* (Fig. 8) which is kept closed when the udder is not in use by a sphincter of smooth muscular fibres.

When the udder is diseased the appearance of the substance of the gland may be greatly altered. In cases of tuberculosis, there may be small or large clusters of buff yellow opaque patches of necrosed or caseous matter, some of these may be calcified, sometimes miliary tubercles are observed. In a great number of cases, there are in the midst of the organ more or less extensive patches of tissue denser, more transparent and more red, than the normal glandular tissue. There is a great tendency to the production of fibrous tissue, and in advanced cases the glandular tissue may be almost entirely replaced by fibrous tissue, in such cases the walls of the ducts are considerably thickened and the cistern may be more or less completely obliterated (Fig. 9). In the early stages the parts of the udder which are affected are larger than usual and feel nodulated. As the disease advances the enlargement and induration increase, but in the later stages there may be absorption of degenerated tissues, contraction of fibrous tissue and the udder may be considerably reduced in size.

When the udder is tuberculous the mammary lymphatic gland is generally considerably enlarged and tuberculous. Among the effects of tuberculosis of the udder the desquamation of the epithelial cells lining the acini and ducts of the affected parts is of special interest from a diagnostic point of view. Cells derived from the gland are found in comparatively small numbers in the milk from normal udders, but when the udder is diseased these cells increase considerably in number.* This is not special to tuberculosis, other forms of

* These epithelical cells are much altered and have been frequently mistaken for leucocytes.

FIG. 6.

Transverse section through the posterior quarters of the udder of a tuberculous cow (Birch Hall cow) seen from the back.

Showing the considerable enlargement of the right hind quarter and the alterations in the appearances of the glandular tissue owing to extensive caseation of the greater part of the quarter. The appearance of the glandular tissue of the left hind quarter is nearly normal.

Section made after complete hardening of the organ, and therefore quite flat and not showing the effects of unequal contraction of tissues.

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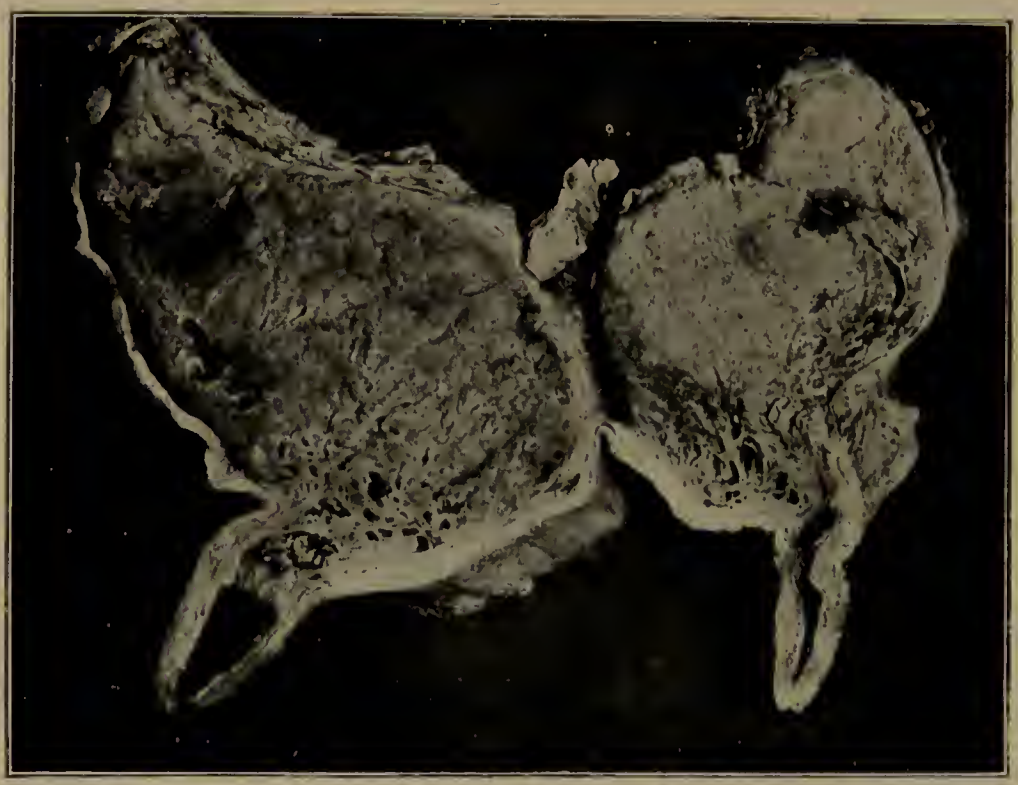


FIG. 7.

Transverse section through the anterior quarters of the udder of a tuberculous cow (Birch Hall cow) seen from the front.

Both quarters are diseased, but the right is much more affected than the left quarter. The cistern of the right teat was distended with curdy-looking matter, of which a small quantity is seen in the upper part of the cistern; this matter was teeming with tubercle bacilli.

Section made before hardening, the unequal contraction of the fibrous tissue, of the normal and of the diseased glandular tissues have rendered the surface uneven; this renders some of the differences between diseased and normal parts more obvious.

FIG. 8.

Antero-postcrior section through the right hind quarter of a tuberculous cow. 12 years old. The udder was healthy and large.

The photograph shows the cistern continuous with the cavity of the teat and the short straight duct of the teat through which the milk escapes from the teat.

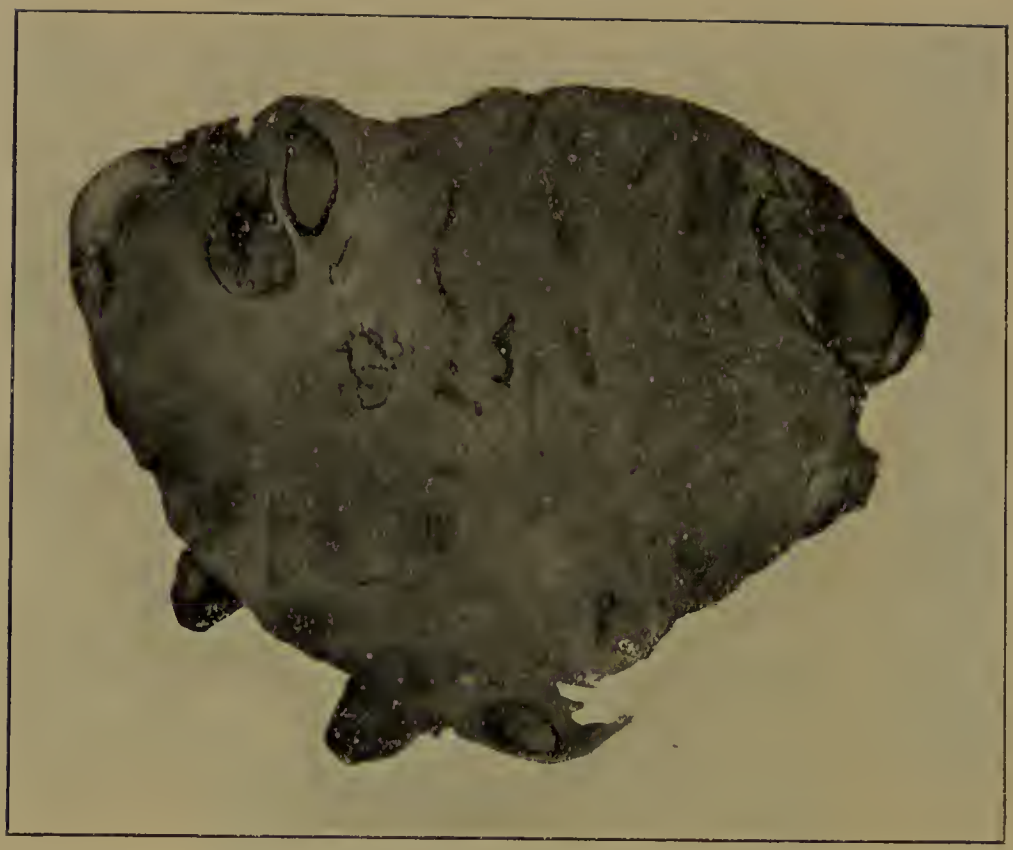


FIG. 9.

Antero-posterior section through one half of a tuberculous udder also affected with catarrhal mastitis. The ducts are considerably distended with muco-purulent material in which very few tubercle bacilli were found. The glandular tissue is almost entirely replaced by fibrous tissue. The cavity of the teat almost entirely obliterated by fibrous tissue. The mammary lymphatic gland is considerably enlarged and tuberculous.

mastitis produce a similar increase of cells. Caseous debris, mucous plugs, fibrinous masses may also be found in the milk. Sometimes tuberculosis is complicated by other infections giving rise to catarrhal or suppurative mastitis, in such cases tuberculous lesions are liable to be overlooked. An example of such a case is shown on Fig. 9.

A good cow often yields from 12 to 14 quarts of milk in 24 hours, some cows give even more milk. In the districts supplying Manchester the average yield is about 8 quarts. Tuberculosis does not cause in its early stage any diminution in the quantity or apparent quality of the milk. I have had under close observation a cow the udder of which was in a fairly advanced state of tuberculosis, and which gave for over 2 months from 7 to 8 quarts of creamy looking milk containing a large number of tubercle bacilli. I have known of another cow with early tuberculosis of the udder that yielded 18 quarts of tuberculous milk in the day. I have also records of a number of cases in which the quantity of tuberculous milk yielded by tuberculous cows was normal or above the normal. When a cow is milked the milker usually sits on a low stool on the right side of the animal, he places the milk pail which has generally a wide opening, between his knees, and steadies the cow by pressing his head against the right flank of the animal, very nearly above the opening of the milk pail. He then takes hold of one teat with each hand and squeezes the milk out of each teat alternately. During this operation the cow is often restless, swishes its tail, kicks, and not unfrequently defæcates and micturates. It is obvious, therefore, that during the operation of milking the milk is exposed to many sources of contamination, more especially when the milker, the cow, and the stable are not clean. The opening of the teat duct is frequently covered with dirt, and the duct itself is more or less contaminated. The first milk drawn, or *fore milk*, is therefore liable to be more contaminated than the rest. The milker generally leaves a little milk in the udder, this *after milk*, or "*strippings*" as it is called, contains a large number of cells. By a kind of massage or manipulation of the udder it is often possible to obtain a few ounces of milk from an udder which appears to have been milked dry, and this milk is particularly rich in cells, and sometimes in morbid products which have been dislodged by the manipulation of the organ.

III.—Sources of the Tubercle Bacilli found in Cow's Milk.

A. *The possible sources of tubercle bacilli* in cow's milk are numerous, they can be classified as follows :—

The secretions or dejecta of the tuberculous cow producing the milk, or of cows kept in the same shed.

1. The muco-purulent *discharges from the respiratory passages*, specially in cases of advanced tuberculosis of the lungs and respiratory passages.
2. The *alvine discharges* where there is disease of the intestinal tract or passage of tuberculous discharges from the respiratory passages into the œsophagus. The dung becomes a serious source of infection when tuberculosis of the intestine causes severe diarrhœa, as it frequently does in the latter stages of the disease.
3. The *urine*, more specially when there is advanced tuberculosis of the kidneys and urinary passages.

4. *Utero-vaginal discharges* in cases of tuberculosis of the genital organs.
5. The *milk* in cases of tuberculosis of the udder and possibly sometimes in cases of advanced tuberculosis without apparent tuberculosis of the udder.

Of these products *tuberculous milk is an unavoidable source of tubercle bacilli.*

The *intestinal and genito-urinary discharges* may *pass directly* into the milk pail at the time of milking, when that operation is conducted negligently, or *indirectly*, by first coating the skin covering the udder, flanks, thighs and tail of the cow; this, however, should not occur when the cow is properly kept and groomed, the milking conducted carefully, and the milk received in proper milk pails. In connection with the detection of tubercle bacilli in dung, it is important to keep in mind the fact that acid-fast bacilli, bearing some resemblance to the tubercle bacillus, may be present in large numbers in the intestinal contents of cows not affected with tuberculosis.

The discharges from the *respiratory and upper alimentary passages* may also at times pass indirectly into the milk by contaminating the cow and various articles in the stable. All these discharges retain their virulence after drying, and may be blown about in the shape of *dust* and infect the cow, the cowman, or any vessel kept in the stable. The milk may also be contaminated with bacteria including tubercle bacilli through the intermediation of flies.

The cowman and other dairy hands.

1. It has been supposed by some that *direct and dangerous tuberculous infection* of the milk is frequently caused by tuberculous dairymen, either at the farm or elsewhere. It is obvious that tuberculous men of extremely dirty habits might at times lubricate their hands with their own expectoration before milking the cows, or contaminate the milk in other ways.
2. The expectoration and other discharges from a tuberculous man may also contaminate the stable or his own clothing in the same way as the discharges from a tuberculous cow would, and thus cause *indirect contamination* of the milk.

Various farm animals other than the cow may be a source of *indirect contamination* of the milk. *Swine* are most liable to tuberculosis, but *horses*, *dogs* and *cats* should not be ignored as possible, though rare, sources of tubercle bacilli. Various poultry birds are also very liable to the disease, *i.e.*, *turkeys*, *geese*, *ducks*, *hens*, &c.

The *dairy vessels* may become infected, not only when kept in the stable, but when handled by dirty or tuberculous dairy hands, or "cleaned" with water highly polluted with the drainage of infected stables.

Of all these sources of infection some are *unavoidable, constant and generally massive*, others are *avoidable, accidental, and are generally slight.*

B.—*The udder as a source of infection of the milk.*

The tuberculous udder is now, as was always my opinion, rightly considered to be by far the most important source of

tuberculous milk. This view is corroborated by the experience gained during the past 14 years in connection with the Manchester supply with regard to the degree of infectivity of samples of milk and the lesions found post-mortem in the tuberculous cows from which the sample had been obtained.

Between 1895 and 1900 the inoculation of guinea-pigs with the milk of tuberculous cows produced in a large proportion of cases very considerable tuberculous lesions. The udders of the cows that had produced these virulent samples were extensively diseased. During the past few years very few of the milk samples produced extensive lesions, and in many cases the experimental lesions were recognised with some difficulty. This change has been associated with a much greater rarity of clear lesions of the udder; the majority of the advanced cases had been eliminated during the previous years. Owing to frequent testing and inspection it is now practically impossible for tuberculosis of the udder to reach the advanced stages which were at first frequently observed. Advanced cases are, however, still found occasionally in farms that are inspected for the first time, although farmers begin to realise the importance of not keeping on their farms cows with diseased udders or in a state of advanced tuberculosis.

The work of detection of tuberculous lesions by ordinary veterinary examination has therefore become more difficult, but this is in part compensated by the greater skill which the veterinary surgeons have gained by experience.

The number of tubercle bacilli excreted by a tuberculous udder is considerable and at times enormous.

In order to ascertain directly how much milk might be infected by a tuberculous udder I took some of the milk from an udder in a state of advanced tuberculous mastitis, diluted it with various quantities of cows' milk free from tubercle bacilli, and inoculated a series of guinea-pigs with the various dilutions.

The results of these inoculations have been given on page 347 and in Fig. 5 from which it will be seen that one part of the tuberculous secretion was capable of infecting 100,000 parts of sound milk. I regret not to have pushed the dilution further, for the result of the microscopical examination indicated that this milk diluted 1,000,000 times would probably have still been capable of infecting guinea-pigs.

At the time when the udder becomes first diseased there is no diminution in the amount of secretion. Many of the cows which we had to condemn were considered exceptionally "good milkers" by the farmers. It is not unusual for a cow, the milk of which contains a large number of tubercle bacilli, to yield eight, nine or more quarts of apparently excellent milk in a day. The milk of one such cow may therefore be sufficient to infect the milk of a very large herd when the diseased and sound milk are mixed together.

This experiment shows the degree of delicacy to which the inoculation test may be brought. The power which a single cow with a tuberculous udder has to infect a large quantity of milk has been clearly proved by the fact that when it was found at the laboratory that the mixed milk from a farm was capable of producing tuberculosis, the veterinary surgeon was able in the majority of cases to discover a cow with tuberculous udder in the herd.

C.—Other sources of infection than the tuberculous udder.

Of the other sources of infection which I have enumerated it is obvious that the *tuberculous fæcal and genito-urinary discharges of the cow* are the most important, either *directly*, when the cow defæcates and the loose fæces produce abundant splashings while milking is going on, or *indirectly*, owing to the udder, flanks, legs and tail being coated with tuberculous dung which may fall into the milk pail when the udder is handled, the cow steadied by the head of the milker, or the cow swishes its tail.

The dung may contain a large number of tubercle bacilli. It must, however, be admitted that when the cow is properly groomed and handled, and when the milkman is clean and takes a moderate amount of care, the amount of excreta entering the milk pail accidentally must be extremely small. Even when the cow, milkman, and stable are dirty the comparatively small amount of infectious matter introduced in this way is diluted with the milk of several cows and ultimately the number of tubercle bacilli derived from the dung is exceedingly small when compared with the number derived from the udder.

This source of infection, in my experience becomes chiefly important when the tuberculous lesions have become fairly extensive and in such cases the udder is also very frequently affected.

With regard to the *other discharges from the cow* the chances of direct infection of the milk are slight, and the probable amount of indirect infection is very small, when compared with that derived from the udder. The same may be said of tubercle bacilli derived from the *milkman and various farm animals.* Even in the event of human expectorations finding their way accidentally into the milk, the number of tubercle bacilli introduced in this way would be exceedingly small when compared to the number of bacilli that may be derived from a tuberculous udder.

IV.—Experimental Evidence regarding the Chief Source of Tubercle Bacilli in Cows' Milk.

When beginning my work on milk in Manchester, my first observations were directed towards ascertaining to what extent tuberculosis of the udder was the source of the milk found to be tuberculous. My earlier results were summarised in the Journal of Comparative Pathology, June—September, 1897; thus the milk of 24 tuberculous cows was distributed as follows: 10 cows *certainly suffering from some form of mastitis* (tuberculous or not) produced tuberculous milk in five instances, or 50 per cent.; 9 cows whose udders, judging by the characters of the milk, were possibly affected with some form of mastitis produced tuberculous milk in 1 case, or 11 per cent.; and 5 *tuberculous cows with healthy udders* produced no tuberculous milk.

During the period 1896–1901, 505 cows kept on farms producing tuberculous milk showed *evidence of some udder disease.* Of this number 50 only within my knowledge were tested with tuberculin, with positive result in 38 cases, negative in 10 cases, and doubtful in 2 cases. A bacteriological examination of the milk of these 50 cows gave the following results: Of the 38 cows reacting positively to tuberculin 8, or 21 per cent. had tuberculous milk, the non-reacting 12 cows did not give milk producing tuberculosis on inoculation.

The udders of seven of the tuberculous cows which had been found to give milk that had not produced tuberculosis in inoculated animals were examined, post-mortem, and I found them to be *free from naked eye or microscopical tuberculous lesions.* Guinea-pigs inoculated with portions of these udders did not contract tuberculosis.

I also examined five of the udders of tuberculous cows that had given milk producing tuberculosis in inoculated animals, and found *in each of these udders tuberculous lesions visible to the naked eye or under the microscope*, and in all cases tubercle bacilli were found in the lesions.

It may now be accepted that tuberculosis of the udder is the main source of tuberculous milk.

V.—Difficulty of Detecting Early Tuberculous Lesions of the Udder by Inspection and Palpation Alone.

For some time after the onset of tuberculosis in the udder, the lesions are so slight that even an experienced veterinary surgeon may have great difficulty in deciding whether the udder is diseased or not. From an administrative point of view this difficulty is most inconvenient, and we have, therefore, paid special attention to it. I need only refer to four cases inspected by Mr. Lloyd. The mixed milk supplied by three farms having been found tuberculous, these three farms were inspected, but no tuberculous udder could be discovered, the mixed milk of these three farms was again tested bacteriologically and still found to be tuberculous. Mr. Lloyd inspected again these farms, and after a very lengthy examination he discovered in each a cow showing slight signs of disease of the udder, *but in none were the symptoms at all typical of tuberculosis.* A sample of milk was taken from each of these cows, and each of the three samples produced tuberculosis in the experimental animals.

In another case Mr. Lloyd took a sample of milk from a cow suffering from advanced pulmonary tuberculosis, the udder appearing to be free from disease at the time. I found that the milk contained tubercle bacilli ; Mr. Lloyd visited the same farm five weeks after his first visit and detected slight induration of one of the hind quarters of the udder. Two weeks later he examined the cow again and found the induration more marked. He then took a separate sample of milk from each teat and sent those samples to me. Of these four samples only one produced tuberculosis, and this was the sample taken from the diseased quarter.

I have records of several other instances of the same kind, which it is unnecessary to enumerate here. I will simply relate in detail the observations and experiments which I made during the year 1908 upon a tuberculous cow which I kept in my own stable for nearly four months. I obtained this cow for the purpose of repeating a number of experiments and observations which I had made before 1897. There was perfect concordance between the 1908 results and those obtained before 1897.

VI.—Changes observed in the Udder and the Milk of a Tuberculous Cow in the course of Four Months (*Birch Hall cow*).

Towards the end of August Mr. Brittlebank found for me a cow suffering from tuberculosis of the udder. From the examination

which he made of the animal at the farm, he was of opinion that this cow had tuberculous lesions of the left lung and of the right posterior quarter of the udder, he had some doubts about the state of the right anterior quarter, and thought that the left half of the udder was sound. I bought this cow and had it brought to a stable at my house. For purposes of reference I will call this animal the "Birch Hall cow."

On September 10th, i.e., some two weeks after the cow had been first inspected at the farm, Mr. Brittlebank and I examined her carefully and we observed that, in addition to the lesions previously noticed, the right anterior quarter of the udder had become clearly involved :

The right half of the udder was distinctly larger than the left half, the difference was most marked after the cow had been milked. The state of each of the quarters was as follows (Fig. 11 A).

Right posterior quarter, considerably enlarged, projecting downward and backward beyond the corresponding quarter on the left side, generally indurated, irregularly nodulated hard mass felt in the anterior part of the quarter in front of the base of the teat.

Right anterior quarter, slightly larger than the left anterior quarter, softer than the right posterior quarter, an ill-defined patch of induration felt by pressing the hand between the anterior parts of the two halves of the udder. The right anterior quarter although clearly abnormal was very much less affected than the right posterior quarter.

Left posterior and anterior quarters, nothing abnormal detected.

The amount of milk yielded by the cow at that time was 7 to 8 quarts in 24 hours, there was no marked difference between the amount obtained from the right and from the left half of the organ. The milk had the appearance of good creamy milk. The results of the bacteriological examination of the milk are given in the table at page 359.

It will be sufficient to state here that the only visible difference between the samples of milk obtained from each of the four quarters was that the milk of the two right quarters had a slight brownish tinge. This slight colouring of otherwise normal looking milk is not observed only in tuberculous mastitis but also in various other forms of mastitis. Tubercle bacilli could easily be detected in the milk of the two right quarters by the microscopical method. *Two tubercle bacilli* were found after long search in four milligrams of sediment from the *milk of the left anterior quarter.* The guinea pigs inoculated with the milk of the two right quarters and of the left anterior quarter contracted tuberculosis. The milk of the left posterior quarter had no effect.

On September 26th.—A complete examination of the cow was again made 16 days after the second examination and about one month after the first (by Mr. Brittlebank). The cow was in fairly good condition, its coat was glossy, but the animal was thin and coughed occasionally. The physical signs of pulmonary disease were more marked. The right side of the udder was considerably enlarged (see Fig. 11 B) and both right quarters were much indurated and nodulated. An ill defined nodule or patch of induration could now be felt in the depth of the left anterior quarter close to the abdominal wall. The left posterior quarter appeared to be normal. The amount of milk yielded at one milking by the

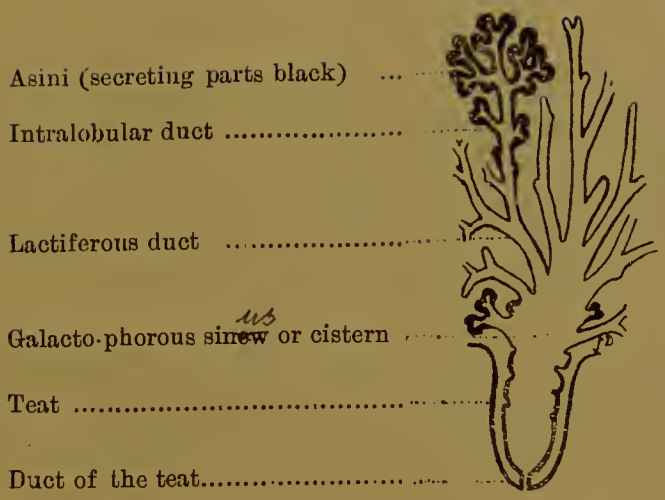


FIG. 10.

Diagram of the essential parts of a cow's udder.

FIG. 11.

Udder of the "Birch Hall" cow. Changes observed between September 10th and December 28th.

A.—Udder seen from below, anterior part above in sketch. September 10th. Right side distinctly larger than left.

B.—Udder seen from below, anterior part above in sketch. September 26th. Right side much longer, right mammary lymphatic gland very large and distinctly felt.

C.—Udder seen from below, anterior part above in sketch. December 28th. Considerable enlargement and nodulation of right side. Mammary lymphatic glands much enlarged.

D.—Udder seen from the right side, to show enlargement of right half and bulging of each quarter above the teat. The dotted line indicates approximately the size of the left half of the udder.

Parts which felt indurated during life are indicated by stippling.

To face p. 356.

right half of the udder was 500 ccs., by the left half of the udder 1250 ccs.

The total amount of milk produced on the 24th was about 4 litres or a little less than one gallon. This milk appeared normal, but that obtained from the right half had the brownish tinge previously noticed. The milk of the right posterior and anterior quarters and of the left anterior quarter contained tubercle bacilli and produced tuberculosis in guinea pigs. The milk of the left posterior quarter was normal and guinea pigs inoculated with it remained healthy.

Between September 28th and October 1st, the temperature of the animal was taken several times, and on September 30th, at 9 o'clock p.m., the animal received a subcutaneous injection of 3 ccs. of tuberculin. The temperatures observed were as follows :—

September 28th	9 a.m.	101° 6.	
„ 29th	„	101° 4.	
„ 30th	„	101° 4.	
„ „	9 p.m.	102° 2	Tuberculin injected.
October 1st	6.30 a.m.	103° 2.	
„	7.30 „	104° 4.	
„	8.30 „	105°.	

There was therefore a very clear positive tuberculin reaction.

Samples of milk were taken immediately before the injection of tuberculin and at 9 a.m. on October 1st during the height of the tuberculin reaction. The injection of tuberculin did not seem to produce any effect upon the virulence of the milk. The milk from the left posterior quarter remained normal, and produced no effect when injected into guinea pigs (see table of results page 359). During the month of November the cow became gradually weaker and coughed more frequently, the right side of the udder continued to enlarge, and the lesions in the left anterior quarter became more distinct. The left posterior quarter remained apparently free from disease. The milk from the right quarters had begun to be distinctly altered early in October, being more translucent than the milk from the left half of the udder. It was comparatively of low specific gravity : 1,028, 1,029, 1,030, 1,032, 1,033 ; it also contained a large number of cells and of tubercle bacilli. The milk of the left anterior quarter had a slightly higher specific gravity : 1,030, 1,032, 1,032, 1,032 ; it contained many cells but not so many on an average as the right quarters, tubercle bacilli were much more scanty and not always demonstrable by the microscopical method.

The milk of the left posterior quarter had the highest specific gravity : 1,035, 1,031, 1,035, 1,035 : it contained fewer cells than the milk of the other quarters, and up to the beginning of October never contained any tubercle bacilli. The examination of the milk was unfortunately interrupted during the months of November and December.

At the beginning of December the cough became very troublesome, and the cow began to suffer from violent diarrhœa which became rapidly fœtid. There were many tubercle bacilli in the fluid fæces. The secretion of milk stopped and it was with difficulty that Mr. Brittlebank was able to obtain a few ounces of a yellow serous looking fluid, full of whitish flocculent masses from each of the two right quarters. He could not obtain any secretion from the left quarters.

On December 24th the cow was slaughtered and a post-mortem examination was made by Mr. Brittlebank, who found advanced tuberculous lesions of the lungs, thoracic and mesenteric glands. On examination of the intestine I found extensive superficial ulcers or erosions which had not the usual characters of tuberculous ulcers. There were many tubercle bacilli in the débris and mucus covering the floor of these ulcers. The right side of the udder was about three times as large as the left side.

The right posterior and the right anterior quarters were both in the same state, bulging externally, anteriorly and posteriorly above the teat, and projecting considerably downwards, backwards and forward beyond the corresponding quarters on the left side (Fig. 11, C and D). Both felt very hard and nodulated. The left anterior quarter though generally soft contained several indurated patches. The left posterior quarter was small and soft.

In sections of the right quarters hardly any trace of normal glandular tissue could be recognised, the normal tissues had been replaced by clusters of rounded or oval or branched patches of pale yellow opaque material, in which the original arrangement of the acini could be at places recognised. These yellow opaque patches were separated by more translucent pink, reddish yellow strands, containing an excess of fibrous tissue.

In the left anterior quarter, there were only few comparatively small pale yellow patches surrounded by a zone of translucent pink connective tissue.

In the left posterior quarter beyond a slight increase of the opacity of some parts of the glandular tissue no lesion suggesting tuberculosis could be found.

In the cistern of both right teats there was an accumulation of yellowish opaque coagulated looking material, in which tubercle bacilli were very abundant, there was also a large accumulation of the same kind of material in the ill-developed cistern of the right supernumerary teat (behind the ordinary right posterior teat) this material contained a large number of tubercle bacilli.

The mammary lymphatic glands on both sides were tuberculous, but the right was several times larger than the left and contained large caseous masses. All the lesions previously described when examined microscopically were found to contain tubercle bacilli, and to be the seat of diffuse tuberculous lesions. Giant cells and giant cell systems were very few. The chief interest of this case (apart from the evidence which it gives as to the amount of infection that may be derived from a single cow) is in the clear connection observed between the lesions of the udder and the infectiousness of the milk. The milk from the three quarters which were diseased was invariably found infectious. The milk of the sound quarter remained free from bacilli for at least one month, even during the height of the tuberculin reaction. For some time before death there were signs that this quarter was beginning to undergo some change, for there was an increase of cells in its secretion. Unfortunately the cow became rapidly worse, and when an attempt to obtain milk from this quarter was made the secretion had ceased.

The results of the complete examination of samples of milk collected between September 10th and December 24th are summarised in the table of results of 38 experimental inoculations which I performed between the same dates (p. 359).

Results of 38 experimental inoculations made in the course of 3 months and 19 days with the milk of a tuberculous cow with tuberculous udder, kept under observation by the author. (Birch Hall cow.)

Reference No.	Date.	Nature of Sample.		Naked-eye characters of the Milk.	Reaction.	Specific Gravity.	Cream per 100.	Sediment per 100,000.	Inoculation test for tubercle bacilli.		Remarks.	
									No. of days after inoculation.	Degree of tuberculosis.	Average degree for time (standard).	
		A.—Whole Udder.										
7474A	10–IX.	Whole milk of udder mixed.	Cream only used for inoculation.	Normal, creamy looking.	Alk., slight	1,034	5·3	14·	21	2nd	2nd	The cow was yielding 8 quarts of milk at the time.
7475A	,,	Ditto	Sediment only.	Ditto	,,	,,	,,	,,	38	4th	3rd to 4th	The lesions produced by the cream were quite as extensive as those produced by the sediment. The local lesions produced by the cream were more marked. The absorption of the cream was slow.
7474B	,,	Ditto	Cream only	Ditto	,,	,,	,,	,,	32	4th	4th	
7475B	,,	Ditto	Sediment only.	Ditto	,,	,,	,,	,,	19	2nd	2nd	

Continuation.

Reference No.	Date.	Nature of Sample.		Naked-eye characters of the Milk.	Reaction.	Specific Gravity.	Cream per 100.	Sediment per 100,000.	Inoculation test for tubercle bacilli.		Average degree for time (standard).	Remarks.
									No. of days after inoculation.	Degree of tuberculosis.		
		B.—Left Half of Udder.										
7505A	26-IX.	Milk of the 2 quarters mixed.	Sediment used for inoculation.	Normal, creamy looking.	—	—	10·6	25·	27	2nd to 3rd	3rd	
B	„	Ditto	Ditto	Ditto	—	—	—	—	79	4th, advanced.	4th, advanced.	
7529	1-X.	Ditto	Ditto	Ditto	Amphot.	1,037	6·	8·75	32	0	—	Milk taken 11 hours after injection of tuberculin, temperature of cow being 105° F.
		C.—Right Half of Udder.										
7504A	26-IX.	Milk of the 2 quarters mixed.	Sediment used for inoculation.	Milk slightly more translucent than normal, and having a slight brownish tinge. It was nevertheless very creamy.	—	—	9·1	110·	20	2nd	2nd	

B		Ditto	Ditto	Ditto	—	—	—	—	26	4th	3rd	
7528	1-X.	Ditto	Ditto	Ditto	Amphot.	1,035	6·8	52·5	31	4th	3rd	Milk taken 11 hours after injection of tuberculin, the temperature of the cow being 105° F.
		D.—Left Posterior Quarter.										
7477A	10-IX.	*Cream* only used for inoculation.		Normal looking, creamy.	Alk., slight	1,035	15·9	11·	123	0	4th, advanced or death.	
B	10-IX.	*Sediment* only used for inoculation.		Ditto	—	,,	,,	,,	285	0	,,	
7508A	28-IX.	*Fore milk* only, ditto ...		Ditto	—	1,031	5·3	24·	267	0	,,	
B	,,	*After milk* only (strippings), ditto.		Ditto	—	,,	15·2	24·	27	0	3rd	
7520	30-IX.	*Fore, middle, and after milk*, mixed.		Ditto	Amphot.	1,035	12·9	37·5	73	0	4th, advanced.	Before injection of tuberculin (temperature of cow 102·2° F.).
7525	1-X.	Ditto		Ditto	,,	,,	13·6	17·5	14	0	2nd	11 hours after injection of tuberculin, when the temperature was 105° F.
		E.—Left Anterior Quarter.										
7478A	10-IX.	*Cream* only used for inoculation.		Normal, creamy.	Alk., slight	1,032	20·5	30·	97	4th, advanced.	4th, advanced.	
B	,,	*Sediment*, ditto		Ditto	,,	,,	,,	,,	45	4th, beginning.	4th, more advanced.	
7509A	28-IX.	*Fore milk*, ditto		Ditto	—	1,030	4·5	90·	92	4th, advanced.	,,	

Continuation.

Reference No.	Date.	Nature of Sample.	Naked-eye characters of the Milk.	Reaction.	Specific Gravity.	Cream per 100.	Sediment per 100,000.	Inoculation test for tubercle bacilli.		Average degree for time (standard).	Remarks.
								No. of days after inoculation.	Degree of tuberculosis.		
		E.—Left Anterior Quarter—*cont.*									
7509B	28 IX.	*After milk*, only used for inoculation.	Normal, creamy.	Alk., slight	1,030	19·	105·	26	2nd	3rd	This guinea-pig was suffering from accidental gastro enteritis due to infected food.
7521	30–IX.	*Fore, middle, and after milk*, mixed.	Ditto	Amphot.	1,032	9·8	35·	62	4th, early.	4th, advanced.	Before injection of tuberculin (temperature 102·2° F.).
7524	1–X.	Ditto	Ditto	,,	,,	11·4	60·	21	3rd	3rd	11 hours after injection of tuberculin (temperature 105° F.).
		F.—Right Anterior Quarter.									
7476A	10–IX.	*Cream* only used for inoculation.	Creamy-looking, but colour brownish.	Alk., slight	1,029	22·8	150·	33	4th, advanced.	,,	
B		*Sediment*, ditto	Ditto	—	—	—	—	31	,,	,,	
7507A	28–IX.	*Fore milk*, ditto	Ditto	—	1,028	3·8	105·	22	,,	2nd to 3rd	
B		*After milk*, ditto	Ditto	—	—	9·8	50·	23	,,	,,	
7523	30–IX.	*Fore, middle, and after milk*, ditto.	Ditto	Amphot.	1,033	9·1	92·5	22	3rd, early	3rd, early	Before injection of tuberculin (temperature 102·2° F.).

7527	1–X.	Ditto	Ditto	„	1,030	16·7	85·	22	3rd, early	3rd, early	11 hours after injection of tuberculin (temperature 105°F.).
	28–XII.	All the secretion obtainable.	Yellow, serous-looking with flakes.	Alk.	1,028	0	858·	—	—	—	Tubercle bacilli very abundant in the secretion. (No inoculation.)
		G.—Right Posterior Quarter.									
7475A	10–IX.	*Cream* only used for inoculation.	Creamy, brownish colour.	„	1,029	15·2	105·	32	4th, very advanced.	3rd	
B	„	*Sediment*, ditto	Ditto	—	—	—	—	35	4th, advanced.	„	
7506A	28–IX.	*Fore milk*, ditto	Ditto	—	1,028	5·3	120·	26	„	„	
B	„	*After milk*, ditto	Ditto	—	—	9·8	105·	26	„	„	
7522	30–IX.	*Fore, middle, and after milk*, mixed.	Ditto	Amphot.	1,030	9·8	105·	24	4th, early	„	Before injection of tuberculin (temperature 102·2° F.).
7526	1–X.	Ditto	Ditto	„	1,032	11·4	60·	21	3rd to 4th	2nd to 3rd	11 hours after injection of tuberculin (temperature 105°F.).
2034A	28–XII	Secretion diluted 100 times	Yellow, serous-looking fluid with whitish flakes suspended in it.	Alk.	1,028	0	1122·	15	early 3rd	early 2nd	Quantity actually inoculated corresponding to— $\frac{1}{5}$th of one cubic centimeter of milk 0·2 cc.
2035A	„	Ditto 1,000 „	Ditto	„	„	„	„	„	2nd, advanced.	„	$\frac{1}{50}$th ditto 0·02 cc.
2036B	„	Ditto 10,000 „	Ditto	„	„	„	„	„	early 2nd	„	$\frac{1}{500}$th ditto 0·002 cc.
2037A	„	Ditto 100,000 „	Ditto	„	„	„	„	„	beginning 2nd.	„	$\frac{1}{5000}$th ditto 0·0002 cc.

VII.—Apparent Relation between the Amount of Cells and Extraneous Products found in Samples of Mixed Milk and the Pathogenic Properties of the Milk.

As the presence of tubercle bacilli in milk may in some cases be attributable to the introduction of extraneous dirt, it seems desirable to complete these general remarks by referring to the relation which the presence of cells, dirt, and other extraneous products appeared to have to the pathogenic properties of milk. I presented to the Manchester Sanitary Committee a report upon this subject in the early part of 1908. The following statements are taken from that report.

Although my original method for estimating the amount of sediment is not so accurate as my new one described in the second part of this report, it is sufficient for general puposes of comparison.

I have explained how a part of the bacteria, cells, and various products, in other words dirt, were separated from each sample of milk by centrifugalisation. This sediment, when examined microscopically, was found to consist chiefly of :—

1. *Cells* derived from the internal parts of healthy or diseased udders.
2. *Hairs and cells* derived from the skin of the milker, or of the cow or other farm animals.
3. *Wool, cotton, and other fibres* from the clothing of the milker, or from strainers and other articles.
4. *Vegetable and mineral matter* derived—
   (*a*) *From food, dung, litter*, or other kinds of dirt clinging to the skin of the cow or the hands of the milker ;
   (*b*) *From the dust or splashings* in the cow-sheds, or dirt adhering to dairy vessels, when these are not properly cleaned ;
   (*c*) *From the water* used for cleaning the cans and other dairy vessels.
5. *Animalcules, moulds, algae, bacteria* derived from the food, litter, water (used to clean dairy vessels or other purposes), possibly also from the hands and clothes of dirty milkers, and from cows or other farm animals, including cats and dogs.
6. *Pathogenic organisms* derived from diseased cows, dairy hands, polluted water, dust, etc.

It seemed to me that the amount and character of the sediments separated from samples of unseparated milk collected at the farms (or at railway stations on their arrival from the farms) would be greatly influenced by the state of the cow-sheds and dairies.

I paid, therefore, special attention to the amount of sediment separated from each sample of milk received in the laboratory.

The amount was *roughly* estimated by measuring the diameter of the deposit formed in the closed hemispherical end of tubes of uniform diameter which were used for centrifugalising the milk. Taking the average of the last 10 years as my basis, I have come to the conclusion that milk yielding a sediment having a diameter of—

less than ...	7 m.m.	was clean ;
„ „ ...	9 „	was as clean as could be expected under average circumstances ;
„ „	9–10 „	was of doubtful cleanness ;
more than	10 „	was dirty ;
„ „	13–20 „	was very dirty or contained an excessive amount of cells or inflammatory products indicating disease of the udder.

This classification is quite arbitrary, and could not be used for administrative purposes, but is quite sufficient for purpose of comparison.

The weight of slime per gallon corresponding to the various diameters of the sediments may be *approximately* estimated as follows :—

6– 8 m.m.	—at least	10	grains	per	gallon.
9–10 „	„	20	„	„	
11–12 „	„	30	„	„	
13–20 „	„	80	„	„	

To control these figures, I obtained in 1900 the slime separated (at a dairy) from 15 gallons of average country milk. This material was kindly supplied to me by Mr. Hailwood. The weight of this slime was 304·45 grains, *i.e.*, about 20 grains per gallon. Milk containing this amount of slime generally yielded in the laboratory a sediment measuring 9–10 m.m.

Between the years 1896–1900 the average amount of slime arriving daily in 40,000 gallons of milk may be calculated as follows :—

						grains.
179	samples at	10	grains	per gallon	... ...	1,790
218	„	20	„	„	... ...	4,360
45	„	30	„	„	... ...	1,350
12	„	80	„	„	... ...	960
454						8,460

$$\frac{8{,}460 \times 40{,}000}{454 \times 7{,}000} = 106 \text{ lbs. of slime.}$$

The amount of slime arriving daily was, therefore, about 106 lbs., or 1 ton in 20 days. (On the supposition that the daily supply was about 40,000 gallons.)

In 1906 the amount of slime in the same quantity of milk had been reduced to 79 lbs.

Some of the constituents of slime are natural cellular products, which are not of an objectionable nature. From the observations made in my laboratory it appears difficult to obtain regularly milk containing less than seven grains of sediment per gallon. Admitting this to be the irreducible minimum, it is possible to estimate roughly the *unnecessary and objectionable amount of slime* imported daily. Before 1900 this objectionable slime amounted to 66 lbs. daily; in 1906 it had been reduced to 39 lbs.

Between 1896 and 1900 over 60 per cent. of the milk samples examined gave sediments measuring 9 m.m. or more; in other words only 40 per cent. of the milk appeared to be clean.

In 1906 the milk had improved considerably; over 68 per cent. of the milk gave sediments below 9 m.m., and could, therefore, be classed as clean milk.

The diminution in the number of milk yielding sediments of 13 m.m. and over, and which, according to the scale adopted, were classed as very dirty, was even more marked. Between 1897 and 1900 not less than 2·6 per cent. of the samples belonged to this group, while in 1906 the percentage had fallen down to 0·5, *i.e.*, the number of very dirty samples had fallen from 5 to 1.

The results obtained are summarised in Table B. and Diagram II. In this diagram all the lightly shaded part above the black line indicates the relative quantity of clean milk during the 10 years; the darker shaded parts under the black line show the relative amount of milk of doubtful cleanness; the black portion represents milk which contained much dirt or an excessive number of cells, presumably derived from diseased udders.

This great diminution in the amount of dirt may, I think, be taken as conclusive evidence that during the last 10 years a very marked improvement has taken place in the state of cows and cow-sheds. It is obvious that if the milk had been treated at a dairy before the taking of the samples, the amount of dirt in the milk would not have had the meaning attached to it here. The samples collected at the railway stations came directly from the farms and, except for the usual straining, had not been freed from a great part of the slime by centrifugalisation.

Milk contractors are now in the habit of "cleaning," by centrifugalisation or filtration the milk arriving from the farm. But centrifugalisation cannot be trusted for the removal of dangerous bacteria. I have explained previously (page 343) that many bacteria, cells and other light particles remain in the cream. Therefore, artificially cleaned milk is not equal in safety to milk clean from the first. Before reaching the contractor the milk is almost invariably strained at the farm, but only the gross impurities are partly removed by straining.

The strainer is often a source of bacterial contamination. The pouring of milk through the layer of dirt on the surface of the strainer causes the displacement of finer particles, including the bacteria clinging to the grosser particles.

Although there is no constant relation between the amount of dirt and the pathogenic properties of milk, when individual cases are considered, there is, on the contrary *a distinct average correlation between the amount of dirt and the pathogenicity of untreated milk.* This is shown not only with regard to tuberculosis, but also in connection with other lesions which are liable to occur in inoculated animals.

I have classified roughly all the lesions which were observed in the course of this investigation into five groups, which are indicated in Table A. and Diagram 1. From these it will be seen that in 1897 and 1898 not less than 45 per cent. of the samples produced some kind of lesion (including tuberculosis), whilst in 1906 the percentage had fallen to 14·4 (including tuberculosis). In 1897–8, 3·6 per cent. of the samples produced severe septicæmic lesions rapidly fatal; since 1902 no sample of this kind has been received.

Diagram I. shows better than Diagram II. the great improvement which has taken place in the Manchester milk supply during 10 years of close sanitary supervision. All the portions of the diagram above the black line correspond to the *milk which was proved by actual experiment to be free from noxious properties*, and, therefore, could be considered wholesome. Only 54 per cent. of the milk belonged to that category in 1897–8; in 1906 the amount of wholesome milk had risen to 84·7 per cent. The milk capable of producing serious lesions (including tuberculous lesions), which in 1897–8 amounted to 20·8 per cent., had in 1906 been reduced to 7·4 per cent.

Table A.

Results of Inoculation of Guinea Pigs with the Sediment obtained from 40 cc.'s of Milk in each case.

Manchester.—*Unseparated Mixed Milk taken at Railway Stations and other places away from the Farm*—i.e., *Milk such as would have been supplied to the contractor or the consumer in Town. In this table of gross results control samples are included.*

Year.	Group I. Normal.		Group II. Chronic.		Group III. Sub-acute.		Group IV. Acute.		Group V. Tuberculous.		Actual Number of Specimens Examined.	Remarks.
	Actual Number.	Per cent.	Actual Number.	Per cent.	Actual Number.	Per cent.	Actual Number.	Per cent.	Actual Number.	Per cent.		
1897–8	60	54·5	27	24·5	—	—	4	3·6	19	17·2	110	Group I.—Normal—No lesions observed attributable to milk.
1900	243	70·5	50	14·5	10	2·9	2	0·6	39	11·3	344	
1901	329	75·0	64	14·6	3	0·7	—	—	42	9·5	438	Group II.—Chronic—Evidence of various forms of inflammation, not fatal or very slowly fatal and clearly attributable to milk.
1902	292	68·0	78	18·4	15	3·5	2	0·47	36	8·5	423	
*1903	303	69·4	70	16·0	9	2·0	—	—	54	12·3	436	
1904	331	76·7	53	1··2	5	1·1	—	—	42	9·7	431	Group III.—Sub-acute—Various lesions attributable to milk, and fatal to one or both animals from 4 to 10 days after inoculation.
1905	633	82·8	58	7·5	12	1·5	—	—	61	8·1	764	
1906	601	84·7	50	7·0	6	0·8	—	—	47	6·6	704	Group IV.—Acute—Lesions attributable to milk and fatal to one or both animals within 3 days.
											3,650	Group V.—Tuberculous lesions.

* During this year a number of farms which had not previously been inspected were included in the operations.

Table B.

Amount of Sediment separated by Centrifugalisation.

Manchester.—*Unseparated Mixed Milk taken at Railway Stations, or at other places away from the Farm.*

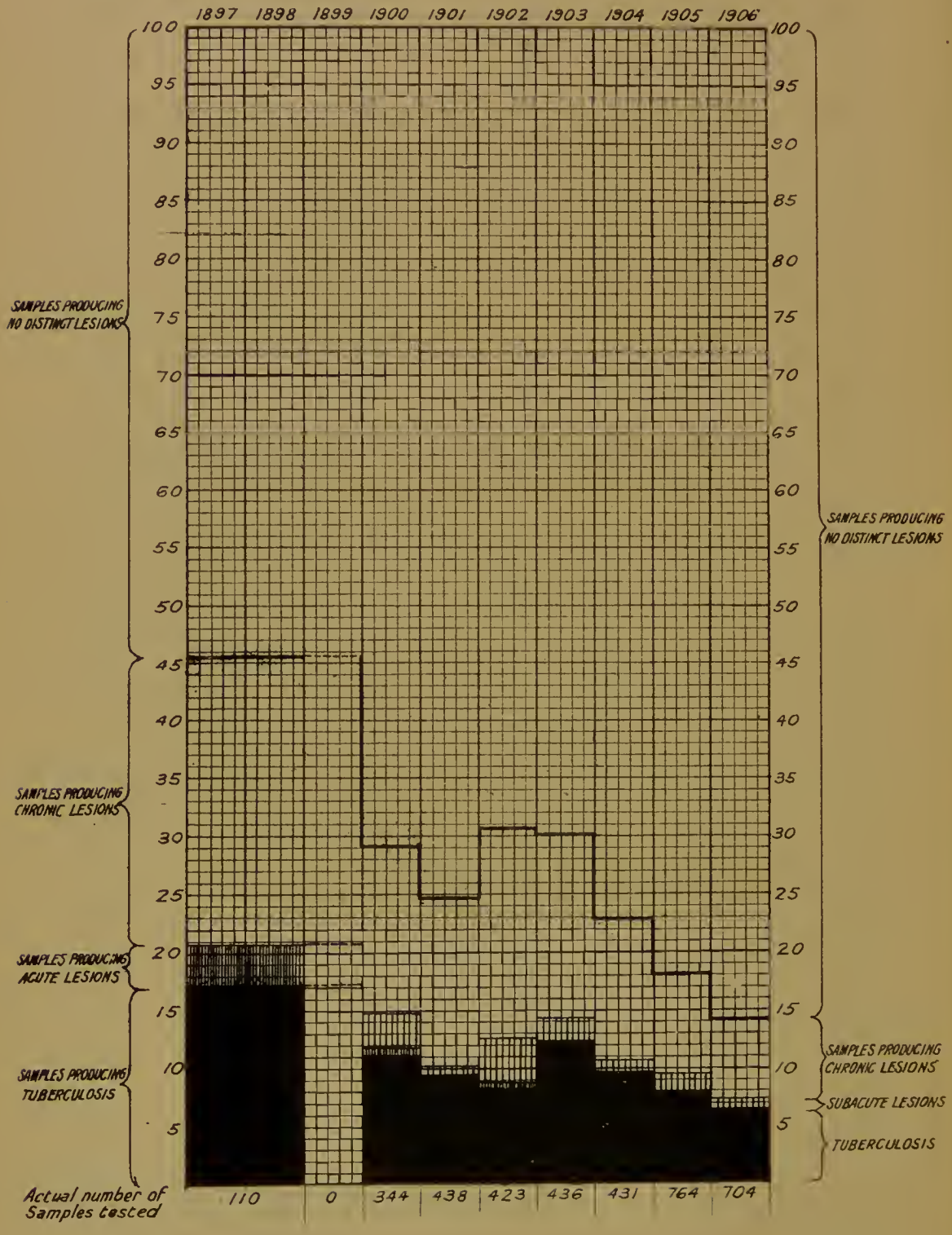
Years	Clean Milk.				Doubtful.		Milk contained marked excess of Dirt or Abnormal Products.				Total.
	Under 7 mm.		7–8 mm.		9–10 mm.		11–12 mm.		13–20 mm.		
	Actual Number.	Per cent.	Actual Number.	Per cent.	Actual Number.	Per cent.	Actual Number.	Per cent.	Actual Number.	Per cent.	
1896–1900	19	4·2	160	35·2	218	47·9	45	9·9	12	2·6	454
1901–1902	186	21·5	325	37·7	280	32·5	53	6·1	17	1·9	861
1903–1904	164	18·9	295	34·0	326	37·5	57	6·5	15	1·7	867
1905	190	24·8	276	36·1	242	31·6	49	6·4	7	0·9	764
1906	185	26·2	296	42·0	188	26·7	31	4·4	4	0·5	704
											3,650

The numbers indicating the amount of sediment show only the relative amount. The absolute amount of sediment is not given in this table.

Diagram I.

3650 Samples of Mixed Milk collected at Railway Stations in Manchester during the 10 Years 1897-1906. (inclusive).

Classified according to the effects produced in inoculated animals.



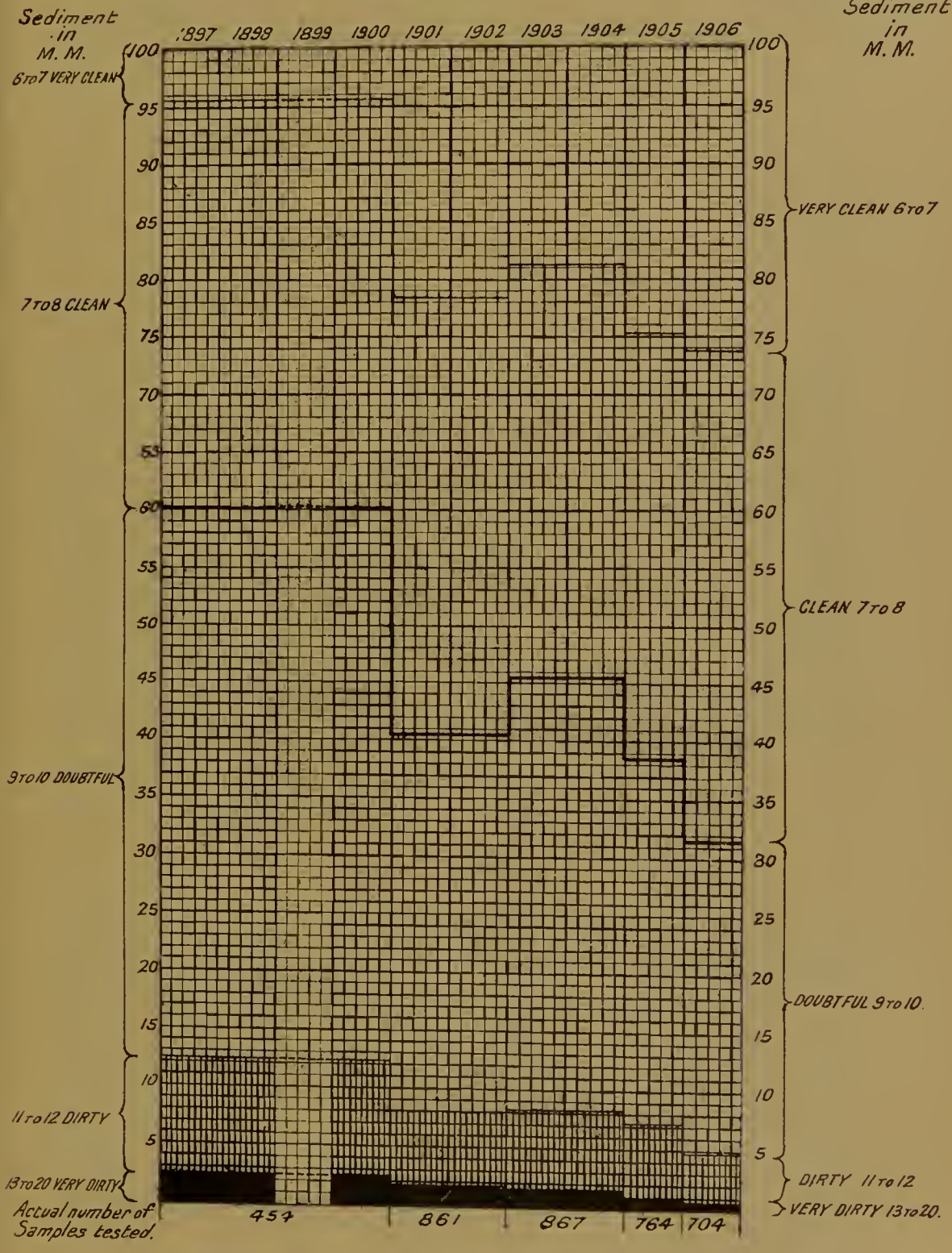
3/12. WT 13002. 24. 1375. 10/09.

Weller & Graham, Ltd Litho, London.

Diagram II.

3650 Samples of Mixed Milk collected at Railway Stations. in Manchester during the 10 Years 1897–1906. (inclusive)

Classified according to the amount of Sediment. (Dirt and Cells)



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PART II.

Results of the Examination of 7,000 Consecutive Samples of Milk for the Detection of Tubercle Bacilli.

I.—Source of the Samples; Number of Samples Available for Investigation Purposes.

The 7,000 samples of milk tested at the Public Health Laboratory between the years 1896 and 1908 were sent by the following authorities:—

Manchester...	—	5,443
Salford	296	
Blackburn	161	
Derby	260	
Sheffield	116	
Burton-on-Trent	314	
Bristol	77	
Various other places	306	
Spoilt samples	27	
	—	1,557
Total ...		7,000

I have avoided any selection of samples, and taken from my books the 7,000 samples that have been sent consecutively to me since 1896. I have, however, been obliged to exclude 82 of these samples as unsuitable for the purpose of this report. Their unsuitability is due in most cases (67 per cent.) to the incompleteness of the data supplied at the time the samples were sent, and the impossibility of obtaining accurate particulars at a later date; in some cases the tests failed to give definite results owing to accidents; in a few cases the samples were unsuitable for the application of any test.

The samples excluded owing to accidents may be taken as representing administrative or experimental failures. Of these failures less than half were due to accidents occurring in the laboratory (chiefly the early death of the two animals inoculated). Of all the suitable samples reaching the laboratory not more than 0·20 per cent. were wasted owing to experimental accidents. After excluding all the unsuitable samples the number remaining for consideration are as follows:—

Manchester samples	5,388
Other samples	1,530
	6,918

The samples sent in small numbers and intermittently from various places are of interest only for general purposes of comparison, and cannot be used in an investigation of the meaning of results. After the exclusion of these 306 samples there remain

6,614 samples

which can be safely utilised for careful study.

These samples were obtained from 2,079 farms in the course of 11 years. The number of cows kept on these farms may be estimated as follows:—

Manchester supply	1,385 farms	Average No. of cows per farm	19·5	Total ...	27,032
Other places	694 „	Average No. of cows per farm	18·0	„ ...	12,492
	2,079				39,524

The number of farms and of cows that have been tested in connection with the Manchester milk supply is about two-thirds of the total number tested for all authorities. The number of samples examined for the Manchester authority is more than three-quarters of the total number of samples sent by all authorities. Table VII. and Table VIII., in which the results obtained are given year by year, show that the inspection work has been pursued more steadily in Manchester than elsewhere, and also that the area from which the Manchester milk came corresponds closely with the milk producing areas of the other authorities (with the exception of the Bristol area). For these various reasons, and also owing to the fact that I have been in very close touch with the work of the Manchester Medical Officer of Health and veterinary inspectors, I will consider in greater detail the results obtained in Manchester, and use the figures relating to other areas for purposes of general comparison.

II.—General Outline of the Administrative Aspect of the Work.

A.—*Farms outside the City boundaries.—Administration of the Milk Clauses of the Manchester General Powers Act*, 1899.

A recent account of the working of the Milk Clauses from the administrative point of view is given in the "Report on the Health of the City of Manchester, 1907," by Dr. James Niven (page 160).

No changes have been made since 1899, and most of the preliminary administrative work done between 1896 and 1899, *i.e.*, before the passing of the Manchester Milk Clauses, was conducted on the same lines. There has, however, been a gradual improvement in the arrangements for the taking of samples, which, since 1901, have been most carefully systematised so as to secure general and frequent supervision of the whole area of supply. The collection of samples and the inspection of farms are conducted as follows. Samples of milk are obtained at the railway stations, or elsewhere within the city, by the Food and Drugs Inspectors. These samples are submitted to bacteriological examination. All samples found to cause tuberculosis are followed to their source at the farm by the medical officer of health (or his representative) and the veterinary surgeon.

The veterinary surgeon examines all the milk cows on the farm, and takes separate samples of milk from cows having diseased or suspicious udders. These samples are examined bacteriologically, and when the milk of a cow is found to be tuberculous this is taken as proof that the udder is tuberculous. The farmer is required by the medical officer of health to isolate the affected cow and at the same time is advised to have the animal slaughtered in the presence of the veterinary surgeon of the corporation. This advice is followed in a great number of cases, and opportunity is thus obtained not only to remove dangerous cows but also to control the value of the bacteriological tests.

It sometimes happens that the farmer disposes of one or more cows in the interval between the taking of samples and the completion of the bacteriological examination. When this has taken place the veterinary surgeon attempts to trace the movements of any cow that has been removed from the farm. In this he is not always successful, owing to farmers frequently sending the suspicious cows to farms that are not under the administrative control of Manchester.

When none of the samples obtained from udders showing evidence of some form of mastitis resembling tuberculous mastitis are found

by bacteriological examination to be tuberculous, further mixed samples are taken either at the railway station or at the farm, and if the mixed milk remains infectious a further inspection of the farm is made. Unmixed samples are again taken and examined bacteriologically.

At first the finding of udders yielding tuberculous milk was sometimes very slow, and in such cases I advised the dividing of the herd into groups of cows varying in number according to the size of the herd, a mixed sample being taken from each group. It was generally found that one of the groups yielded tuberculous milk, and it became then usually easier to find the infective cow or cows. This method has not been used of late in Manchester but it has proved useful in other places. The final step consists in taking one or more samples of the mixed milk of the farm or shippon after the cow or cows with tuberculous udders have been isolated or eliminated. If these control samples are proved by bacteriological examination to be incapable of producing tuberculosis the farm is considered, for practical purposes, to be free from sources of tuberculous infection of the milk *for the time being.*

B.—*Farms within the City Boundaries.*

The cow-sheds within the city are usually inspected without the preliminary examination of a mixed sample of milk. When inspection, palpation of the udder, and other signs do not allow the veterinary surgeon to determine whether an udder is tuberculous or not, a sample of the milk from the suspected udder or quarters is taken for bacteriological examination. During the years 1896 to 1901 inclusive, the cows in nearly all the Manchester cow-sheds were tested in this way. Since then very few samples have been tested bacteriologically, except in 1905, when a fairly large number of mixed samples were taken of the milk supplied by Manchester farms that had not previously been tested bacteriologically. Since then the farms have been controlled by veterinary inspection, and only occasional unmixed samples taken to clear the nature of suspicious cases. The cows kept in the city cow-sheds are frequently replaced, and are on an average much younger than those kept in many country farms; tuberculosis of the udder is therefore much less likely to occur in the city than in the country.

III.—Working Staff.

The success of the work has depended :—

1st. On Dr. Niven's excellent administrative arrangements for the systematic supervision of the milk supplying area and the removal of infectious cases.

2nd. On the special veterinary knowledge and tact of Messrs. Jas. King, Alfred Holburn (1896, 1897, 1898), J. S. Lloyd (1899–1900), and Mr. J. W. Brittlebank (1901–1908) who have successively acted as veterinary surgeons to the corporation.

3rd. On the accuracy of the bacteriological results.

I conducted myself between 1892 and 1895 all the experimental work upon which, in 1895, I based the methods which have been used since then. The examination of samples of milk was also at first carried out entirely by myself, but after the administrative and laboratory work had been fully co-ordinated I secured the co-operation of several of my assistants in succession. A great part

of the bacteriological work has in this way been done by Dr. E. J. Sidebotham, and later by Dr. A. Sellers, who have made under my direction a great number of inoculations and *post-mortem* examinations of inoculated animals.

A fairly large number of *post-mortem* and microscopical examinations have been made for me in early days by Dr. F. J. H. Coutts. Dr. J. R. Carver and Dr. F. C. Moore have also examined microscopically four to five hundred milk sediments. Before any part of the work was transferred to any of my assistants we worked jointly until the results obtained by us were in perfect agreement. As there has been no change in the methods I adopted in 1895 the results obtained at the present time are strictly comparable with those obtained in 1895.

IV.—Collection of Samples and of Data relating to them.

The collection of samples entirely free from accidental contamination is obviously essential to success.

A.—*Collecting apparatus.*

The inspector is provided with collecting apparatus which I have designed specially for the purpose. This apparatus consists of :—

(1) A glass bottle (8 to 10 ozs. capacity) with an indiarubber stopper.

(2) A tinned copper milk scoop, with long handle, shaped like the milk measures used by milk men.

(3) A copper metal case enclosing the scoop and bottle.

The bottle, stopper, scoop and copper case are cleaned and then sterilized by steam under pressure at the laboratory. The inspector has strict instructions not to open the case till the moment when he wants to use it, and to close it again immediately after taking a sample. The stopper must not be allowed to come in contact with any unsterilized object. It is usually deposited in the lid of the sterilized case while the bottle is being filled.

B.—*Collection of mixed milk.*

The Food and Drugs Inspector is instructed to include in a test sample some of the milk contained in the various milk cans coming from a shippon or farm. Care is taken to prevent the admission of any dirt when the milk cans are opened. The milk in each can is stirred up with the sterilized milk scoop, the inspector being careful not to allow his hand to come in contact with the milk. Obviously it would be difficult and inadvisable to stir thoroughly the whole of the milk contained in a milk can, and I have often found samples containing a marked excess of cream, indicating imperfect admixture, this however does not materially affect the results of the bacteriological examination.

During the first years I had the temperature of the milk taken at the time of collection and at the time of arrival at the Laboratory. For this purpose a thermometer was attached to the stopper of the sample bottle. Since 1901 this step has been omitted as sufficient information had previously been obtained.

C.—*Collection of unmixed milk.*

Samples of unmixed milk are collected by the veterinary surgeon at the time of his visit to the farm. The greatest care is taken to avoid

the admixture with the milk of dirt from any source. Skilled veterinary inspectors milk the cow direct into the bottle. Those with less practice may milk the cow into the sterilized scoop or case and transfer the milk into the bottle. *None of the dairy vessels are used for this work, nor is the milkman allowed to take the sample or to handle the collecting apparatus.* In dealing with cases of early tuberculosis of the udder, in which lesions are so slight that they are difficult to recognise by palpation, it is usually preferable to collect the last milk known as *strippings* in which cells and tubercle bacilli are usually more numerous than in the fore and middle milk.

D.—*Collection of data.*

Immediately after taking a sample of mixed milk at a railway station or elsewhere, the inspector fills the form which I supply for the purpose, and of which a facsimile is reproduced here.

N.B.—After entering on this label all the information obtainable, the sample of milk should be sent to the **Director of the Public Health Laboratory, Manchester,** without the slightest delay. If an interval of more than six hours must elapse between the time of milking and the time of arrival of the sample at the Laboratory, the bottle containing the sample should be packed in ice. Suitable refrigerators may be obtained by application at the Laboratory.

Milk collected at Railway Stations, or other places away from Farm.

Name of station or place ..... No. on Lab. Case.....
Name of farm.....of farmer.....
Situation of farm .....
Probable time of milking .....
Railway station nearest to farm.....
Destination of Milk.....
State of milk can.. .....Size.....gallons. No. on Can.....
Temperature of milk.....
Has the sample been collected in such a way as to avoid accidental contamination ?.....
Date of collection.....
Signature of Inspector.....Authority.....

For samples of milk collected at the farm I supply another form for the use of the veterinary surgeon.

N.B.—After entering on this label all the information obtainable, the sample of milk should be sent to the **Director of the Public Health Laboratory, York Place, Manchester,** without the slightest delay. If an interval of more than six hours must elapse between the time of milking and the time of arrival of the sample at the Laboratory, the bottle containing the sample should be packed in ice. Suitable refrigerators may be obtained by application at the Laboratory.

Milk collected at Farm or Dairy.

No. on Lab. Case.....
Name of farm.....of farmer.....
Situation of farm.....
Mixed milk. { State of shippon .....
No. of cows in shippon.....
Unmixed milk. { Description of cow, or No. of reference .....
State of cow .....
General evidences of disease .....
State of the udder.....
Result of tuberculin test.....
Quantity of milk yielded in 24 hours .....
Date of Collection of sample.....A.M.....P.M.
Time of milking .....A.M.....P.M.
Has the sample been collected in such a way as to avoid accidental contamination ?.....
Signature of Inspector .....Authority.....

By means of these forms I have been able to follow closely the progress of the work done and of the results obtained. It was, however, not always possible to obtain all the information required at the time when the samples were collected. Whenever this was the case the missing particulars were obtained by the Veterinary Surgeon during his subsequent visits to the farms. All samples not sufficiently documented have been discarded.

E.—*Forwarding the samples to the Laboratory.*

When the inspector can arrange to deliver the sample at the Laboratory within a few hours of the time of collection, no further precaution is needed than to keep the metal case securely closed until delivery. If the milk cannot reach the Laboratory within four or five hours in the summer or ten hours in winter, the collector is directed to place the sample cases in a small portable refrigerator in which cooling is obtained without the bottles being soiled by melted ice. The refrigerator which I supply for the purpose is of the same type as one which I have used since 1893 for the sending of samples of water to a distance.*

When the samples cannot be examined immediately on arrival at the Laboratory they are kept in a refrigerating chamber at a temperature below 4° C. until they are examined.

V.—Examination of Samples at the Laboratory.

A.—*Preliminary examination.*

The reaction and specific gravity of each sample are taken and any abnormal appearances noted. (The temperature was also taken during the first years.)

The milk is then centrifugalised. For this purpose I use tubes measuring 14 cm. (5½ inches) in length and 2·2 cm. (⅞ inch) internal diameter. The bottom of these tubes is hemispherical and they have two marks indicating the level reached respectively by 2 cubic centimetres and 40 cubic centimetres of fluid.

Two of these tubes are filled up to the 40 ccm. mark with the milk contained in one sample bottle, 80 ccm. (or 2·81 ounces) of each sample are therefore used for the test.

The milk is centrifugalised in these tubes for 15 minutes, the speed of the centrifugal machines (diameter 17 inches) ranging between 2,000 and 3,000 revolutions per minute.

At the end of that time the cream should form a compact layer, so dense that (when the milk is not very abnormal) the tube can be turned upside down without any spilling of fluid. A dense sediment ("slime" of dairymen) is formed at the bottom of the tube to which it adheres so firmly that the supernatant fluid can be entirely removed without the sediment being displaced. In the case of mixed milk this sediment never covers the whole of the hemispherical bottom of the tube and its amount can be roughly estimated by measuring the diameter of the segment occupied by the deposit. The unmixed secretion obtained from diseased udders frequently yields a sediment so bulky that it may fill the whole bottom and rise in the tube to a height of ½ to 4 or more centimetres.

For the purpose of measuring more accurately the amount of sediment, I have of late years used tubes which I designed

* Bacteriological Survey of "Surface Water Supplies," *Journal of State Medicine London, 1898.*

for the purpose. These tubes measure 11·5 cm. in length, the internal diameter of the upper two-thirds is 1·5 cm. that of the lower one-third is reduced to 2 mm. in some, 3 mm. or 4 mm. in others. The narrow part of the tube is calibrated and graduated, the intervals between the divisions corresponding to 5 cubic millimetres.

The lower end of these tubes is open and ground flat.

When the tube is used the lower opening is closed by a hemispherical glass bead, the flat surface of which is ground. This bead is fixed to the tube by covering its flat surface with a thin layer of hot gelatine and pressing it firmly against the lower ground end of the tube. The capacity of these tubes is 15 cubic centimetres. This quantity of milk yields on centrifugalisation enough sediment for purposes of mensuration. When the sediment is scanty 40 cc. or 50 cc. of the milk are centrifugalised in larger tubes of the same shape, or in the ordinary tubes. When the latter are used the milk is centrifugalised as usual, then the cream and separated milk are removed, the sediment, mixed with 15 ccs. of normal saline solution, is transferred to one of the small graduated tubes and centrifugalised again. When the amount of sediment is large, the milk should be diluted before centrifugalisation. The speed of the centrifugal machine is gradually increased until it reaches 3,000 revolutions per minute, at the end of 15 minutes the sediment has separated into several distinct layers, the deepest one containing most of the mineral matter and larger particles of extraneous matter, the more superficial layer being mostly composed of cells and bacteria. The various parts of the sediment can be studied by removing the fluid above it and the bead at the bottom of the tube. The sediment can then be driven out of the tube on to a slide where it forms a cylindrical mass easily analysed. By means of these tubes it is therefore possible not only to estimate with fair accuracy the total amount of sediment, but also to recognise by simple inspection the relative amount of *extraneous matter* which is generally black, grey, greenish or brownish in colour, and of *cellular products* which have usually a creamy, buff yellow, or pinkish (when blood stained) colour and are opaque or translucent. The same elements may be to a certain extent be recognised in the sediments obtained in the larger tubes where they form concentric zones, but owing to their being spread over a larger surface they form thinner less distinct layers. The narrow tubes have allowed me to detect tubercle bacilli by the microscopical method much more frequently than I had been able to do when I used only the large tubes. When dealing with a set of samples of unmixed milk I have been able to detect tubercle bacilli microscopically in 4 out of 10 samples, the remaining 6 samples being found by inoculation to be free from tubercle bacilli. With the large tubes I have seldom been able by the microscopical method to find tubercle bacilli in more than 50 or 60 per cent. of the samples.

This fact is of some importance as, in the event of direct inspection of farms being adopted, as a primary step, the microscopical method might be used to reduce considerably the number of inoculations which up to lately have been found necessary in order to secure accurate results.

To remove the cream and separated milk so as to obtain the sediment by itself the cream is loosened from the sides of the tube and aspirated through a tube ($\frac{1}{8}$-inch diam.) connected with a receiving flask from which the air is exhausted by means of an air pump; the separated milk is then removed in the same way until there remain only 2 cubic centimetres of it with the sediment at the bottom of the tube.

I have also used with advantage for the same purpose, centrifugalising tubes the lower part of which, containing the sediment, could be separated from the body of the tube after centrifugalisation. By tilting the tube the surface of the sediment is exposed and, with a sterilized platinum loop, about 2 milligrammes of the superficial layer of the sediment are taken and spread on a cover glass. One microscopical film is prepared in this way from each of the 2 tubes used for each sample.

After removing this small fraction of the sediment the tube is thoroughly shaken so as to mix the sediment with the small amount of separated milk left with it. The mixture is drawn from each tube into a hypodermic syringe. One syringe, recently sterilized by steam under pressure, is used for each sample. One guinea-pig is inoculated with the contents of each syringe.*

B.—*Microscopical examination.*

The two films when dry are placed in a covered capsule containing equal parts of absolute alcohol and ether, in which they are kept for at least 2 hours, after which the capsule is placed in a dish of water previously brought to a temperature of 80° to 90° C. The mixture of absolute alcohol and ether boils at once, and after 10 to 15 minutes of this treatment the cover glasses are removed from the hot mixture and washed with absolute alcohol.

The films are then stained for tubercle bacilli with carbol fuchsin according to the Ziehl-Neelsen method.

By adopting these precautions very clear preparations are obtained, and no difficulty is caused by acid fast bacilli.

Since 1884 several thousand films have been examined in this way by myself or my assistants and I have known of one instance only in in which an acid-fast bacillus had been mistaken for the tubercle bacillus by a worker who had probably neglected some of the precautions indicated above, and had not paid sufficient attention to the morphological features of the organism, which were clearly different from those of the tubercle bacillus. The reliability of this method of microscopical examination has been amply proved by the results of the inoculation of guinea-pigs. Over 100 samples of milk in which the presence of tubercle bacilli had been demonstrated by the microscopical method produced *without exception* tuberculosis in guinea-pigs inoculated with them.

Unfortunately the failure to find tubercle bacilli by the microscopical method does not prove that a sample of *mixed milk* is safe, and about 50 per cent. of the tuberculous samples would have been overlooked had the routine microscopical examination alone been relied upon. With regard to *unmixed milk* better results may easily be obtained by the special method which I have previously described.

C.—*Inoculation Test.*

Two guinea-pigs weighing from 7 to 10 ozs. (smaller and larger guinea-pigs may be used, but the best results are given by animals of the size indicated above) are inoculated each with the sediment obtained from 40 cc. of milk mixed with 2 cc. of the separated milk in the way which I have previously described. This material is injected subcutaneously on the inner side of the left hind leg, the puncture is made at the level of the femoro-tibial articulation, with aseptic precautions. The two animals inoculated

* For more details see "The Examination of Cows' Milk for the Detection of Pathogenic Properties," *Journal of Comparative Pathology, 1897.*

with one sample are then kept in a recently sterilized zinc cage which is placed in a clean, well-lighted, and well ventilated animal house. The animals are well cared for and regularly fed, the cages are cleaned every day or every other day.

When the precautions previously described are strictly observed, accidental deaths are of great rarity and the inoculations have no appreciable effect on the health of the guinea-pigs unless the milk contains pathogenic organisms. Acute inflammatory lesions are of great rarity even when the milk has been obtained from diseased udders (tuberculous or not).

With milk which has not been properly handled and in which bacteria have been allowed to multiply under the influence of long keeping and high temperature, early inflammatory lesions often rapidly fatal are frequent*, and sometimes interfere with the diagnosis of tuberculosis by causing the death of the animals before the tuberculous lesions have become distinct. When tubercle bacilli are moderately abundant in the milk, enlargement of the popliteal and superficial inguinal lymphatic glands close to the seat of inoculation can often be recognised from the 8th to the 10th day, and if the animal is killed it is fairly easy to demonstrate the presence of tubercle bacilli in these glands (Figs. 1, 2, and 3). (By the inoculation method it is even possible to show that the popliteal gland is usually infected before the end of the 4th day.) When tubercle bacilli are few the lymphatic gland lesions may not be obvious before the end of the 2nd or 3rd week. It has therefore become my practice in order to give uniformity to the procedure and to obtain comparable results to kill the experimental animal at the end of the third week. Very little is gained by waiting longer, for the distinction between various races of tubercle bacilli is not the object of these inoculations.

With regard to milk containing an extremely small number of bacilli that are often very unequally distributed, it is clear that the presence of these bacilli could be detected with certainty only if a greater quantity of milk and a greater number of guinea-pigs than those employed for the purpose of the ordinary routine tests were used.

Besides tuberculous lesions, the milk is capable of producing some other chronic lesions to some of which the name of *pseudo-tuberculosis* has been given. Pseudo-tuberculosis has been erroneously supposed to be a serious cause of error. No experienced pathologist could mistake in the guinea-pig such lesions for true tuberculous lesions, and when the precaution which I have invariably taken of confirming each diagnosis by a demonstration of tubercle bacilli in the lesions occurring in the experimental animal is adopted even an experimenter with scanty pathological experience could not make any mistake.

VI.—Record of Work and Results.

The working of the various methods which have been previously described is made clear by the following reproduction of two pages of my laboratory books which show how a summary record has been kept of all the examinations made since 1896.

---

* The results of the examination of 45 samples of mixed milk collected in 1896 without special precautions were as follows :—

Samples producing no noxious effects or only transient trivial lesions ...	17
Samples producing local irritation, but no general infection	17
Samples producing intense local irritation and general infection ...	8
Samples producing tuberculosis	3

A.—*Records of the examination of two samples of milk, obtained from one farm,* (1) *mixed milk obtained at a railway station,* (2) *unmixed milk obtained at a farm.*

(Record 1).

No.—*3773 M/C. Can 36.* Sanitary Authority—*Manchester.*

Name of Collector, *D. Hickman.* Date of arrival of sample—*23/3/1906.* hour 2 a.m. p.m.

Address if necessary Date of collection ,, ,, ,, ,, hour 7 a.m. p.m.

Time of milking ,, —*23/3/1906.* hour 5 a.m. p.m.

A. Milk collected at Farm or Dairy.

Name of farm of farmer

Situation of farm

Mixed Milk—

State of shippon or shippons

No. of cows in shippon

Unmixed Milk—

Description of cow, or No. of reference

State of cow

Evidences of disease

Result of tuberculin test

Quantity of milk yielded in 24 hours

B. Milk collected from cans at railway stations or other places away from the farm.

Name of station, or place—*Longsight Station.*

Name of farm—*T. O. H.* of farmer—*H. W.*

Situation of farm—(*Map XXI. 84. M. 51.*)—*Prestbury.*

No of miles from Manchester Station

Railway station nearest to farm

Destination of milk—*W. C., Ardwick Terrace.*

State of milk can—*Clean.* Temperature of milk

Characters of Milk on arrival at the Laboratory.

Colour—*Normal.*

Reaction—*Amphoterous.*

Sp. Gr.—*1031.*

Cream—*15 mm.*

Sediment—*11 mm.*

Microscopical Examination of Sediment.

Foreign bodies

Cells Leucocytes

Microbes

Tubercle bacilli

Additional Information.

References :—

Inoculation Book

Laboratory Book

Special Book—*M.B. 5156–5157.*

Photographs

Result of Inoculation + (*20/4/1906*).

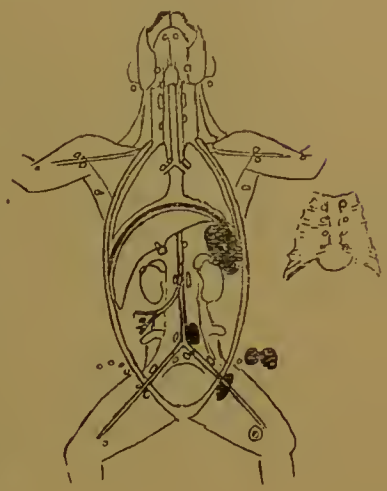
No —*5063*

F. Weight a.m.—*8 ozs.*
Weight p.m.—*8.*

A.

Date of inoculation—*23/3/1906.*
No. of hours after collection—*About 10.*
Part inoculated—*Left hind leg.* quantity—*2 cc.*
Symptoms
Apparent cause of death—*Killed by chloroform.*
Date of death—*18/4/1906.* No. days after inoc.—*26.*
Date p.m.—*18/4/1906.*
Local lesion—*None noticeable.*

Popliteal gland	Right—*Normal.*	Left—*Enlarged, partly caseous.*	
Superficial inguinal g.	id.	id.	
Deep inguinal g.	id.	id.	
Sublumbar g.	id.	id.	
Retro hepatic g.		Bronchial g.	
Mesenteric g.		Sternal g.	
Renal g.		Cervical g.	
Liver		Peritoneum	
Spleen—*Enlarged, a few tubercles.*		Pleura	
Lungs—*Normal.*		Pericardium	

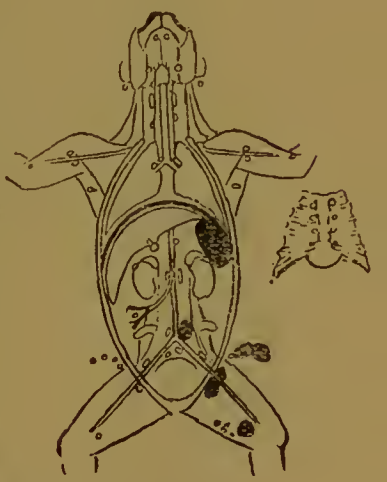


M. Weight a.m.—*7 ozs.*
Weight p.m.—*8.*

B.

Date of inoculation—*23/3/1906.*
No of hours after collection—*About 10.*
Part inoculated—*Left hind leg.* quantity—*2 cc.*
Symptoms
Apparent cause of death—*Killed by chloroform.*
Date of death—*18/4/1906.* No. days after inoc.—*26.*
Date p.m.—*18/4/1906.*
Local lesion—*Small caseous masses.*

Popliteal gland	Right—*Normal.*	Left—*Enlarged, partly caseous.*	
Superficial inguinal g.	id.	id.	
Deep inguinal g.	id.	id.	
Sublumbar g.	id.	id.	
Retro hepatic g.		Bronchial g.	
Mesenteric g.		Sternal g.	
Renal g.		Cervical g.	
Liver		Peritoneum	
Spleen—*Enlarged, a few tubercles.*		Pleura	
Lungs—*Congested.*		Pericardium	



Lesions examined microscopically.	Results.
A.—Popliteal gland (left)	*Tubercle bacilli found.*
Superficial inguinal gland (left) ...	,, ,, ,,
B.—Popliteal gland (left)	,, ,, ,,
Superficial inguinal gland (left) ...	,, ,, ,,
Lesions from which cultures made.	

(Record 2).

No.—*3843 M/C. Can 39.* Sanitary Authority—*Manchester.*

Name of Collector—*J. W. Brittlebank.*

Address if necessary

Date of arrival of sample—*26/4/1906.* hour a.m. p.m.
Refrigerator.

Date of collection „ —*25/4/1906.* hour *11* a.m. p.m.

Time of milking „ — *ditto.* hour *11* a.m. p.m.

A. Milk collected at Farm or Dairy.

Name of farm—*T. O. H.* of farmer—*H. W.*

Situation of farm—(*Map XXI. 84. M. 51.*)

Mixed Milk—

State of shippon or shippons—*Fair.*

No. of cows in shippon—*10* (*on farm, 61*).

Unmixed Milk—

Description of cow, or No. of reference—*Red cow, shed 6, last on left.*

State of cow—*Fair condition.*

Evidences of disease—*Udder, left hind quarter indurated and enlarged, right hind quarter indurated.*

Result of tuberculin test

Quantity of milk yielded in 24 hours—*?*

B. Milk collected from cans at railway stations or other places away from the farm.

Name of station, or place

Name of farm of farmer

Situation of farm

No. of miles from Manchester Station

Railway station nearest to farm

Destination of milk

State of milk can Temperature of milk

Characters of Milk on arrival at the Laboratory.

Colour—*Normal.*

Reaction—*Amphoterous.*

Sp. Gr.—*1034.*

Cream—*7.*

Sediment—*11.*

Microscopical Examination of Sediment.

Foreign bodies—*Very few.*

Cells—*Very abundant.* Leucocytes—

Microbes—*Few.*

Tubercle bacilli—*None found.*

Additional Information.

References:—

Inoculation Book

Laboratory Book

Special Book—*M.B. 5063.*

Photographs

Result of Inoculation+ (*22/5/1906*).

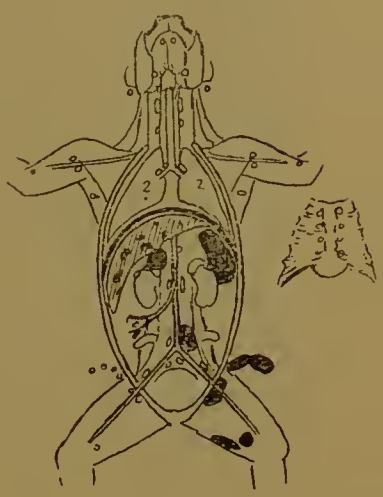
No.—*5157*.
F. Weight a.m.—*8 ozs.*
Weight p.m.—*6*.

A.

Date of inoculation—*27/4/1906*.
No. of hours after collection—*52*.
Part inoculated—*Left hind leg*. quantity—*2 cc*.
Symptoms
Apparent cause of death—*Killed by chloroform*.
Date of death—*21/5/1906*. No. days after inoc.—*24*.
Date p.m.—*21/5/1906*.

Local lesion—*Caseous abscess*.

Popliteal gland Right—*Normal*.		Left—*Enlarged, caseous*.	
Superficial inguinal g. id.	„	id.	„ „
Deep inguinal g. id.	„	id.	„ „
Sublumbar g. id.	„	id.	„ „
Retro hepatic g.—*Enlarged, opaque*.		Bronchial g.—*Normal*.	
Mesenteric g		Sternal g.	„
Renal g.		Cervical g.	„
Liver—*A few small tubercles*.		Peritoneum	„
Spleen—*Enlarged, a few tubercles*.		Pleura	„
Lungs—*Doubtful*.		Pericardium	„



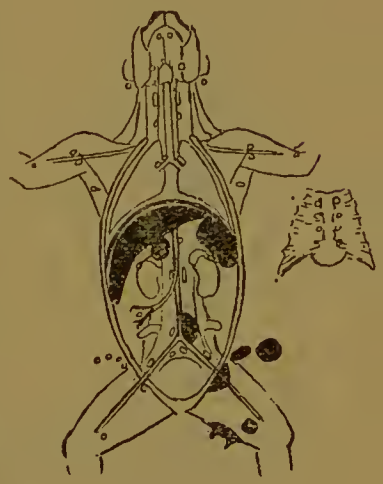
F. Weight a.m.—*?*
Weight p.m.—*4 ozs*.

B.

Date of inoculation—*27/4/1906*.
No. of hours after collection—*52*.
Part inoculated—*Left hind leg*. quantity—*2 cc*.
Symptoms
Apparent cause of death—*Killed by chloroform*.
Date of death—*21/5/1906*. No. days after inoc.—*24*.
Date p.m.—*21/5/1906*.

Local lesion—*Ulcer*.

Popliteal gland Right—*Normal*.		Left—*Enlarged, caseous*.	
Superficial inguinal g. id.	„	id.	„ „
Deep inguinal g. id.	„	id.	„ „
Sublumbar g. id.	„	id.	„ „
Retro hepatic g.—*Enlarged, opaque*.		Bronchial g.—*Normal*.	
Mesenteric g.		Sternal g.	„
Renal g.		Cervical g.	„
Liver—*Tuberculous*.		Peritoneum	„
Spleen— *Ditto*.		Pleura	„
Lungs		Pericardium	„



Lesions examined microscopically.	Results.
A.—Local lesion	*Tubercle bacilli found*.
Superficial inguinal gland	„ „ „
B.—Local lesion	„ „ „
Superficial inguinal gland	„ „ „
Lesions from which cultures made.	

These two records show that on the 23rd of March, 1906, a sample of milk, coming from a farm situated in the Prestbury district, and at which 61 cows were kept, was found at the laboratory to be tuberculous. On the 27th of April the farm was visited by the veterinary surgeon. In a shippon which was in fair condition, and in which ten cows were housed, two cows with indurated udders were found ; one sample was taken from each of these cows. One of the samples was found at the laboratory to produce tuberculosis. To complete the history of this farm I may say that between 1896 and 1900 nine samples of mixed milk had been taken at a railway station, tested bacteriologically and found not to produce tuberculosis. After the discovery and elimination of the tuberculous cow five more samples of mixed milk were taken during the years 1906 and 1907, and none of these were found to produce tuberculosis.

The results are further summarised at my laboratory in cards which allow the state of each farm to be followed closely. A reproduction is given here of the contents of one of the cards which I use for this purpose. The card selected refers to the farm which has already been used as an example.

Farmer : H. W. *County :* Cheshire. *Map :* XXI. 84.
Farm : T. O. H. *District* : Macclesfield. M. 51.

Number in Milk Book.	Place of Collection.* R. F. C.	Date of Collection.	Result.**	Number of Cows.†
92	R.	22.7.1897	—	
519	R.	2.2.1900	—	46
523	R.	2.2.1900	—	
1,514	R.	23.5.1901	—	34
2,337	R.	8.10.1902	—	
2,967	R.	23.10.1903	—	
3,383	R.	27.6.1904	—	
3,731	R.	30.12.1904	—	
4,287	R.	7.7.1905	—	
5,063	R.	23.3.1906	+	61
5,156	C.	27.4.1906	—	10
5,157	C.	27.4.1906	+	10
5,345	R.	23.7.1906	—	
5,760	R.	29.11.1906	—	
5,979	R.	21.2.1907	—	40
6,454	R.	11.7.1907	—	40
6,765	R.	14.10.1907	—	

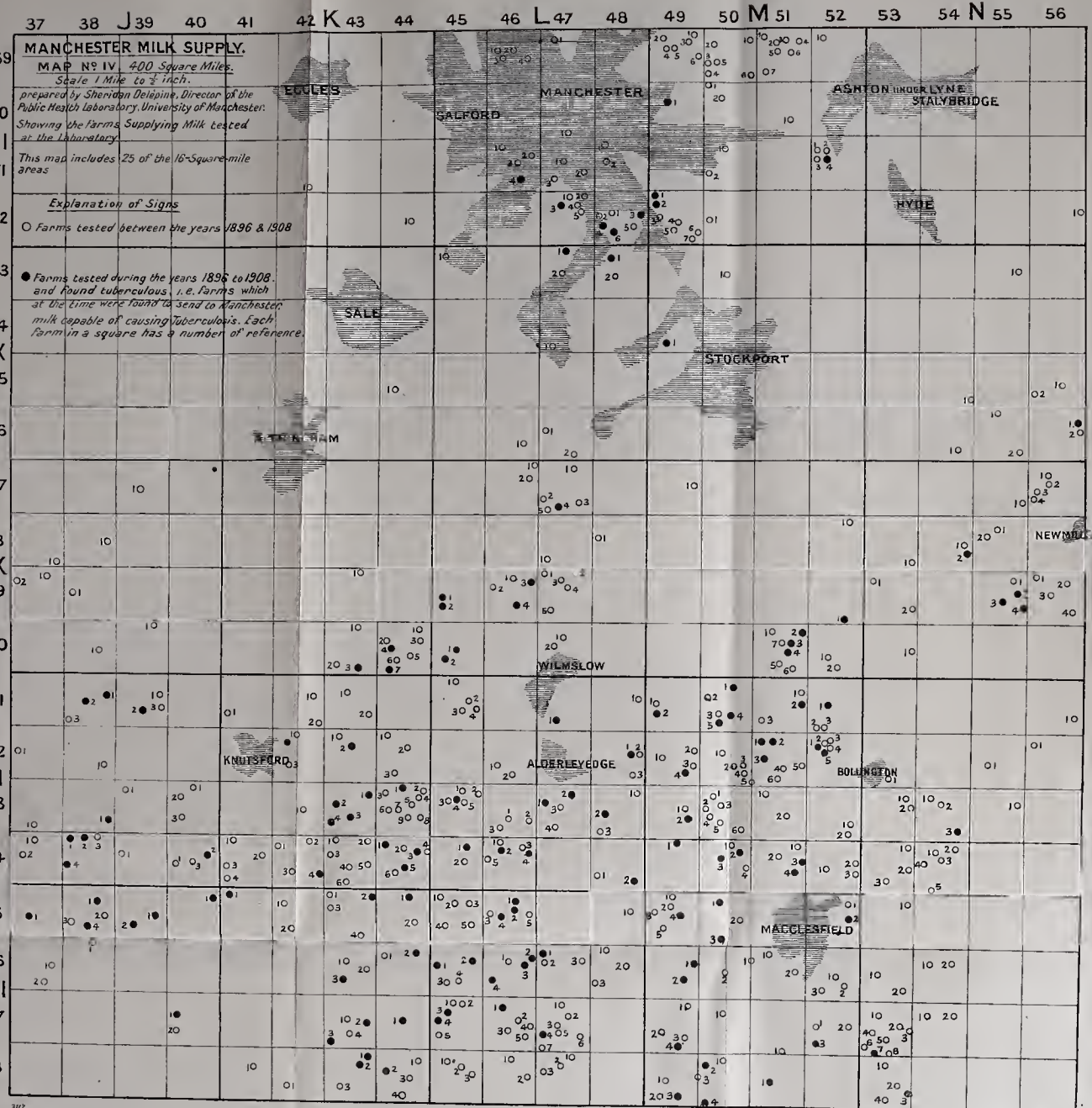
* Place of collection is indicated as follows :—
R. = Railway, or place outside the farm.
F. = Farm, when the sample represents the milk of more than one cow.
C. = One cow only.

** + = Tubercle bacilli found.
— = Tubercle bacilli not found.

† Number of cows means (*a*) in the case of mixed or railway samples the total number of cows in the farm or section of the farm from which the milk found at the railway station is derived ; (*b*) in the case of samples taken at the farm the number of cows in the shippon in which the suspected cows are housed.

B. Map used for studying the distribution of inspected farms and of the farms found tuberculous.

In order to ascertain the distribution of tuberculous cows, I divided into one square inch areas an ordnance map (one inch to the mile) of the whole area supplying milk to Manchester and



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Weller & Graham Ltd Litho London

several other places. The area of each of these squares is, therefore, one square mile. Each of these areas can be identified by two numbers, one of these numbers indicates the distance in miles of the square from the west border of the districts represented on the map and the other number indicates the distance, also in miles, from the north boundary of the map. For the purpose of grouping the farms into larger areas, the map is also divided into latitudinal zones four miles broad, the width of each of these zones corresponds to that of four of the *one-square-mile areas*. Each of these zones is numbered on the map by Roman figures. Four miles zones perpendicular to the former are also indicated in the map by capital letters. In this way the map is divided not only into one-square-mile areas, but also into *sixteen-square-mile areas* which are designated by Roman figures and capital letters. *See* Map IV.

I have given a number to all the farms situated in each one-square-mile area (*see* Fig. 12). It becomes thus possible to indicate exactly the position of each farm in a skeleton map. I have used such a map for the purpose of arranging the records according to the position of the farms.

By this method it is possible to study the distribution of tuberculosis in areas of equal size, a thing which I found impossible to do by means of the usual sub-divisions of the counties into districts of unequal size and very irregular shape.

This kind of map may be conveniently used to show how the testing and inspection of the farms have been conducted year by year, and to record the results obtained. An example of this is given in detail in the map of one 16-square-mile district reproduced here (Fig. 12), and in which each of the farms inspected during the 11 years is indicated by a small numbered ring. The farms inspected each year are tinted grey, and those found tuberculous, black.

C. Detailed table of results obtained in connection with one sixteen-square-mile area.

The detailed tables of results in which the work done between 1896 and 1908 is summarised are so bulky that they cannot be reproduced in this report. I will, therefore, reproduce here only a small section of these tables dealing with the 16-square-mile area XXI. M., the map of which is reproduced in this report. This area is situated in Cheshire, north of Macclesfield. In it, during the 11 years, 57 farms have been supplying Manchester (*i.e.*, more farms than in any other 16-square-mile area). The number of cows in the farms inspected was about 1,022, or a few less than in the area XXII. L., in which there were 1,077 cows distributed among the 50 inspected farms. The proportion of tuberculous farms was above the average, but below that observed in several other areas. Unusual difficulties were experienced in clearing some of the farms from tuberculosis. In the section reproduced here, the names of the farms and farmers have been omitted, but the farms can be identified by the numbers referring to their position on the map.

Table I.

Results of the Examinations of Samples of Milk obtained from Farms situated in the Area XXI. M.

Explanation of signs.—This table is concerned with a little less than $\frac{1}{24}$th of the farms dealt with by the Manchester authority.

The results of bacteriological examination of samples of mixed milk collected at the railway stations or at the farms are given above the line (position of the numerator), the results of the examination of the unmixed milk of individual cows are given below the line (denominator) thus :—

$$\frac{o\ o\ +}{+\ o}$$ means : Two mixed samples not tuberculous, one mixed sample tuberculous (railway samples). / Milk of one cow tuberculous, milk of another cow not tuberculous (individual cows samples).

The order in which the samples have been taken in the course of each year is indicated by oblique lines, thus :

$$\frac{+}{\quad} \Big/ \frac{\overset{F}{+}}{o\ +} \Big\backslash \frac{o}{\quad}$$ which means : Tuberculous railway sample taken before visit to the farm. / Mixed sample taken at the farm, at the same time as the unmixed ; found tuberculous / Visit to the farm after the taking of the first railway sample— one cow giving non-tuberculous milk ; one cow giving tuberculous milk. \ Railway sample taken after visit to the farm and removal of diseased cow; not tuberculous.

F above the sign corresponding to a mixed sample, indicates that the mixed sample was taken at the farm.

Table I. shows that five small farms which were inspected before 1901 have not been inspected since ; this is due to the fact that milk has ceased to come to Manchester from these farms. The same may be said of eight other farms which have not been inspected since 1902 or 1903. On the other hand some 12 farms have been inspected for the first time since 1905. There remains more than one-half of the farms that have each been inspected from 4 to 16 times during the whole period. In comparing the state of the district at the beginning and at the end of the period of 12 years it is necessary to keep account of these facts, but, inasmuch as the farms tested each year were supplying Manchester with milk at the time, the results are comparable as regards the quality of the milk supply at various times.

D.—Amount of milk infected by tuberculous cows.

To obtain a general idea of the amount of tuberculosis that has been dealt with in each area, I have summed up for each area the results obtained during the whole period of twelve years. Whether the contamination of the milk was due to the presence of one or of several diseased cows in the herd, or to any other cause, the mixed milk from that farm was infectious. The amount of tuberculous milk reaching town is, therefore, not proportional to the number of infecting cows, but to the size of the herds to which they belong.

An estimate of the amount of tuberculous milk produced at one time or another within an area can therefore be made by adding together the number of cows kept in the various tuberculous farms. It is unfortunately impossible to ascertain for how long the farm had produced tuberculous milk when the fact was detected.

TABLE I. RESULTS OF THE EXAMINATION OF SAMPLES OF MILK OBTAINED FROM 57 FARMS SITUATED IN THE AREA XXI.M.

REFERENCES TO MAPS: SQ. MILE AREA Nº	FARM Nº	1896–1900	1901	1902	1903	1904	1905	1906	1907	RAILWAY SAMPLES: TOTAL	RAILWAY SAMPLES: +	FARM SAMPLES: TOTAL	FARM SAMPLES: +	Nº OF COWS ON TUBERCULOUS FARMS	Nº OF COWS ON ALL FARMS
89 49	1			00			0	0		4					22
	2 A B	+		0				0	0	4	1			14	14
„ 50	1	0	0	00	00	0	00	+/100\+/1+\0	0	13	2	3	1	30	30
	2						0	0		2					14
	3	0	0	000	0	00	0	0	00	12					19
	4	+/000+00	0 F	+0	0		0		0	7	2	6	1	24	24
	5	0+/+/0	+/0+00\0	000	0+/+	0	0	00		14	4	6	2	12	12
„ 51	1	0		0	0		0	0	000	8					12
	2 A B	0					0	+/++	0	4	1	2	2	8	8
	3 A B	0					0			2					25
„ 52	1	0000	00	+/+0	00	00	0	00+/000\	0	16	2	5	1	27	27
	2	0	0	00	00			0	00	9					12
	3			00	0		0	0		5					12
82. 49.	1	0													10
	2						0	0	0	4					9
	3	000	00	0						6					10
	4	++/0+00	00	00	+/10\		+/+0		0	10	4	7	2	27	27
„ 50	1	0								1					14
	2	0								1					10
	3	0	0	0/100\			0			5		2			14
	4	00	0							3					14
	5	0	0	0						3					23
51	1				0+/+		0	0	0	5	1	1	1	34	34
	2	0		+/0						2	1	1		18	18
	3	+00	00	0	00	0	0	00	0	13	1			17	17
	4						0			1					12
	5							00		2					13
	6	0								1					10
„ 52	1 A B.	+0	0	0+/0+	00			+/00+\00	0	11	3	5	2	18	18
	2			00	0		0		0	5					12
	3	0								1					10
	4	0	00	00		00	0	0		9					20
	5	00		+/+0\00	00		0	0	0	10	1	2	1	12	12
83. 49.	1		0							1					8
	2	+/+0\F+								2	2	2	1	13	13
„ 50	1			00	00	0		0	000	9					13
	2	000	0							4					17
	3	0			0		0			3					14
	4						0			1					17
	5							0	0	2					13
	6						0			1					10
„ 51	1						0		0	2					19
	2	0	00		0	0	0	0	0	8					15
„ 52	1				00					2					13
	2							0		1					22
84 49	1	0	0	00	00		0	0	00	10					25
„ 50	1	0000	0	000	00	00	0	0	000	17					18
	2 A B	0	00	0+/+0	0000	00	0000	0	00	18	1	2	1	16	16
	3		0		0	+/+/0/000\00	0	+/0+0\0		9	3	7	1	23	23
	4 A B.	0	0	0	0	00	0		0	8					28
„ 51	1	0	0				0			3					20
	2						0			1					30
	3	000	0 F	0	0	00	0	+/0+\00	000	15	1	2	1	61	61
	4	00	+/++\0	0	0	0+/00\0		0	0	12	3	4	2	38	38
„ 52	1							0	0	2					14
	2								0	1					20
	3								00	2					18
TOTALS (57 FARMS)		0 —— 29 + —— 7	0 —— 23 + —— 3	0 —— 21 + —— 6	0 —— 22 + —— 3	0 —— 12 + —— 2	0 —— 32 + —— 1	0 —— 23 + —— 6	0 —— 28 + —— 0	328	33	57	19	392	1022

MANCHESTER MILK SUPPLY.

MAP Nº II. *Scale 8 Miles to 1 Inch.* (1896 to 1903.)

Prepared by Sheridan Delépine, Director of the Public Health Laboratory. University of Manchester.

The map is divided into 16 Square Mile areas and smaller 1 Square Mile areas indexed by letters & numbers
IV to XXXIII Horizontal 4 Miles. Zones, numbered From North to South.
13 to 132 " 1 Mile " " " "
A to Z. Vertical 4 Miles " West to East.
1 to 108 " 1 Mile

The districts in which Farms supplying Milk tested at the Laboratory are shown by the following signs.

- Square mile areas with one or more farms tested between 1896 and 1908.
- Square mile areas with one or more farms tested during the years 1897 to 1903 inclusive, and in which no tuberculous farm was found during that period.
- Square mile areas with one or more farms tested during the years 1897 to 1903 inclusive and in which one or more tuberculous farms were found during that period.

Towns used as landmarks to indicate the positions of the districts the name of these towns is given below against the Nº of reference attached to each town.

LANCASHIRE		CHESHIRE	SHROPSHIRE	STAFFORDSHIRE	YORKSHIRE
1. Lancaster	12. Southport	1. Birkenhead	1. Whitchurch	1. Tunstall	1. Hellifield
2. Fleetwood	13. Chorley	2. Stockport	2. Oswestry	2. Burslem	2. Bradford
3. Garstang	14. Rochdale	3. Knutsford	3. Shrewsbury	3. Newcastle-under-Lyme	3. Leeds
4. Clitheroe	15. Formby	4. Macclesfield		4. Hanley	4. Halifax
5. Blackpool	16. Ormskirk	5. Chester	DERBYSHIRE	5. Stoke-upon-Trent	5. Huddersfield
6. Nelson	17. Bolton	6. (Delamere Forest)	1. Chapel-en-le-Frith	6. Uttoxeter	6. Barnsley
7. Burnley	18. Bury	7. Congleton.	2. Buxton	7. Stafford	7. Sheffield
8. Preston	19. Wigan	8. Crewe	3. Bakewell	8. Burton-upon-Trent.	
9. Blackburn	20. Manchester	9. Nantwich	4. Chesterfield	9. Wolverhampton	
10. Accrington	21. Oldham		5. Derby		
11. Darwen	22. Liverpool	MONTGOMERYSHIRE			
	23. Warrington	1. Welshpool			

3/12.

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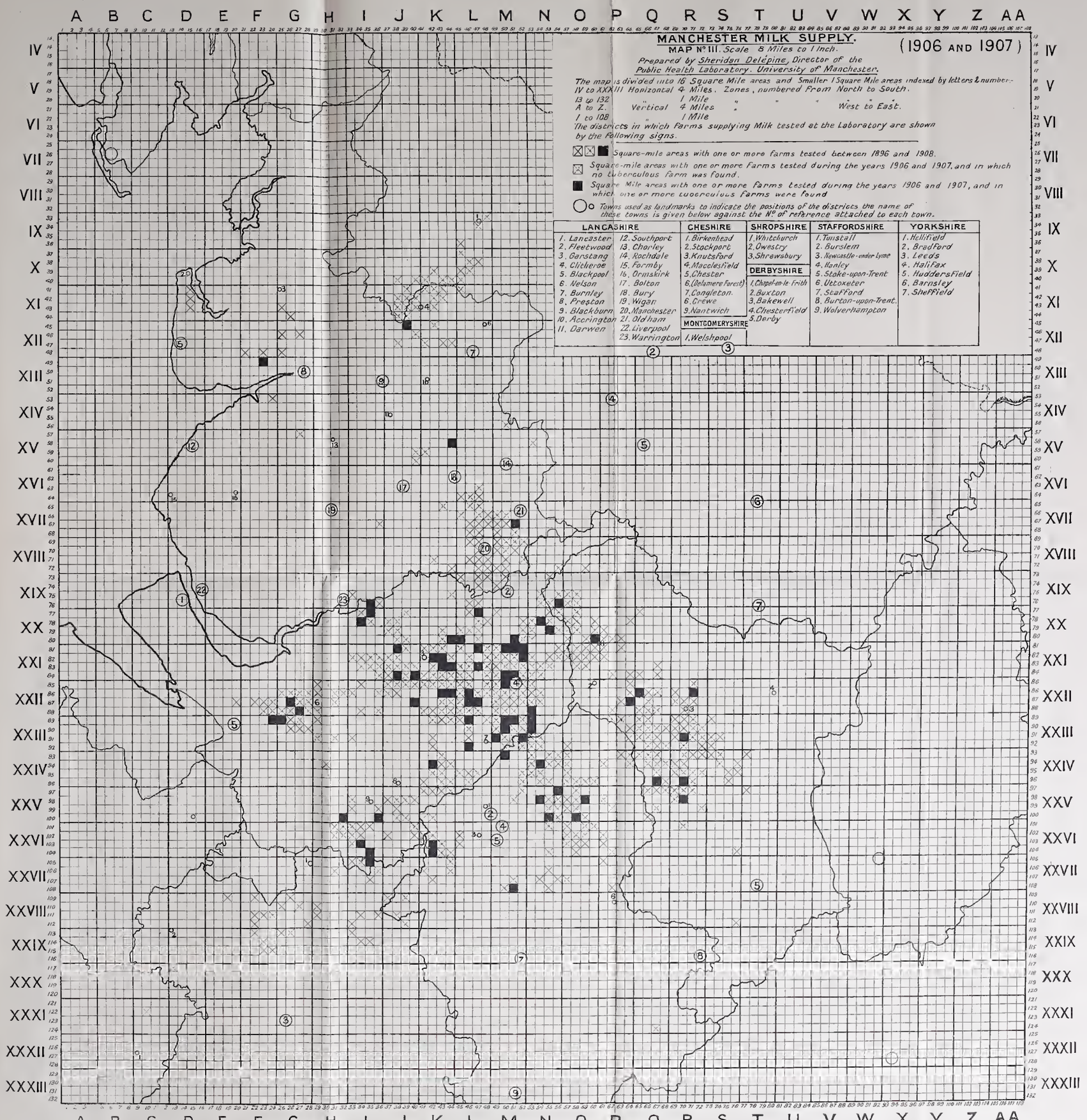

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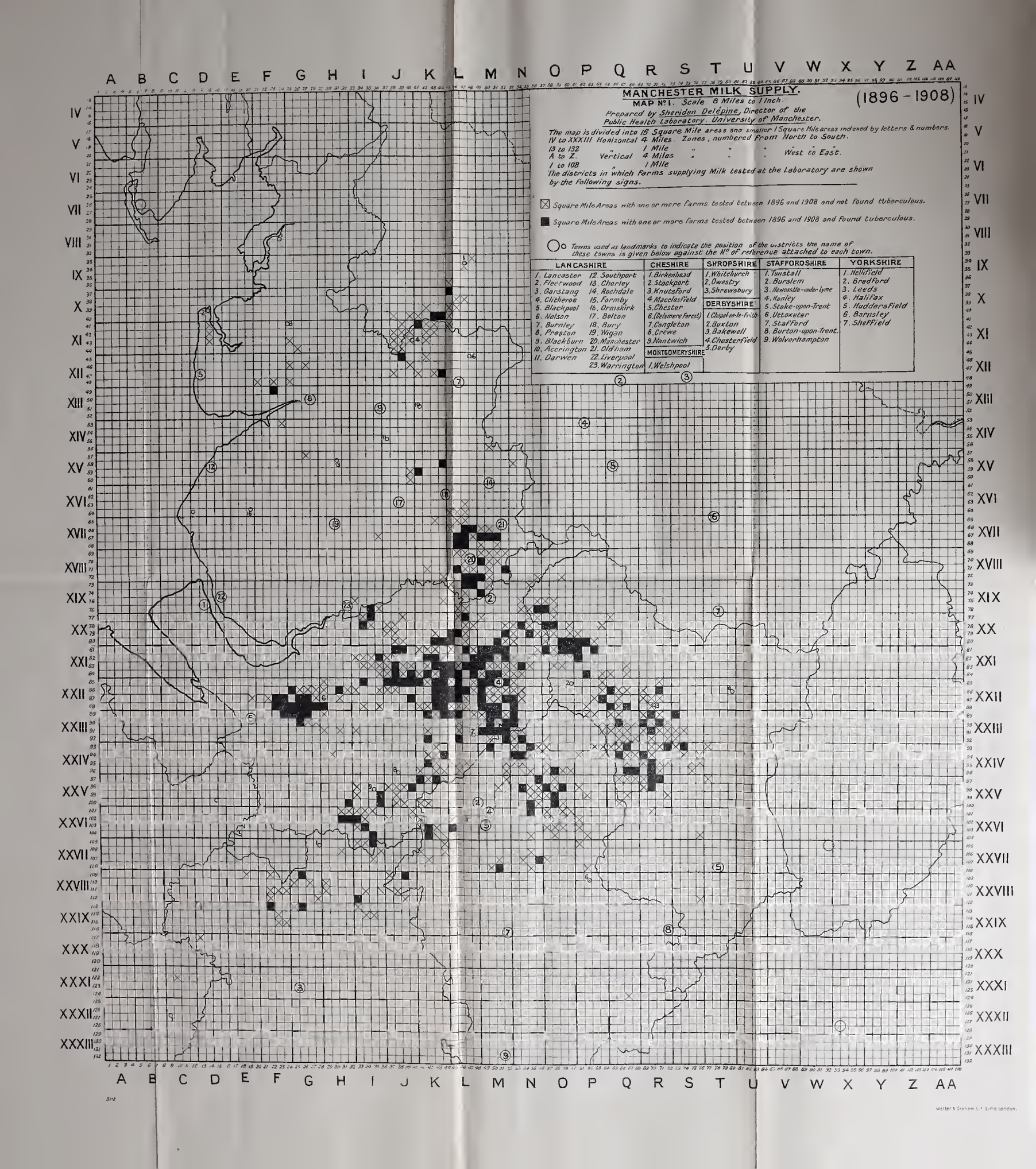
MANCHESTER MILK SUPPLY.
MAP No 1. Scale 8 Miles to 1 Inch.
(1896 - 1908)
Prepared by Sheridan Delépine, Director of the Public Health Laboratory, University of Manchester.
The map is divided into 16 Square Mile areas and smaller 1 Square Mile areas indexed by letters & numbers.
IV to XXXIII Horizontal 4 Miles. Zones, numbered from North to South.
13 to 132 " 1 Mile " " " "
A to Z. Vertical 4 Miles " " " West to East.
1 to 108 " 1 Mile
The districts in which Farms supplying Milk tested at the Laboratory are shown by the following signs.
Square Mile Areas with one or more farms tested between 1896 and 1908 and not found tuberculous.
Square Mile Areas with one or more farms tested between 1896 and 1908 and found tuberculous.
Towns used as landmarks to indicate the position of the districts the name of these towns is given below against the No of reference attached to each town.
LANCASHIRE
1. Lancaster
2. Fleetwood
3. Garstang
4. Clitheroe
5. Blackpool
6. Nelson
7. Burnley
8. Preston
9. Blackburn
10. Accrington
11. Darwen
12. Southport
13. Chorley
14. Rochdale
15. Formby
16. Ormskirk
17. Bolton
18. Bury
19. Wigan
20. Manchester
21. Oldham
22. Liverpool
23. Warrington
CHESHIRE
1. Birkenhead
2. Stockport
3. Knutsford
4. Macclesfield
5. Chester
6. (Delamere Forest)
7. Congleton
8. Crewe
9. Nantwich
MONTGOMERYSHIRE
1. Welshpool
SHROPSHIRE
1. Whitchurch
2. Oswestry
3. Shrewsbury
DERBYSHIRE
1. Chapel-en-le-Frith
2. Buxton
3. Bakewell
4. Chesterfield
5. Derby
STAFFORDSHIRE
1. Tunstall
2. Burslem
3. Newcastle-under-lyme
4. Hanley
5. Stoke-upon-Trent
6. Uttoxeter
7. Stafford
8. Burton-upon-Trent.
9. Wolverhampton
YORKSHIRE
1. Hellifield
2. Bradford
3. Leeds
4. Halifax
5. Huddersfield
6. Barnsley
7. Sheffield
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z AA
IV V VI VII VIII IX X XI XII XIII XIV XV XVI XVII XVIII XIX XX XXI XXII XXIII XXIV XXV XXVI XXVII XXVIII XXIX XXX XXXI XXXII XXXIII
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In Table II. I have attempted to give a synoptical summary of the number of farms, number of cows, and percentage of cows the milk of which was rendered infectious by the presence of tubercle bacilli. Each of the squares in this table represents a 16-square-mile area. In each square the number of farms is given in the left upper angle, the total number of cows in those farms in the right upper angle, the number of cows, the milk of which was infected, per cent of the total number of cows on the inspected farms, is given below the other two numbers. This synopsis shows that tuberculosis was very widely distributed, but was very much more prevalent in certain limited districts than in others. This table refers to the Manchester milk supply only.

E.—Distribution of tuberculous farms.

Map I. shows the extent of the area (2,096 square miles) from which Manchester draws its milk supply. Each square mile area in which one or more tuberculous farms have been found during the 11 years is marked black.

Map II. shows the areas containing farms which were inspected before 1903, and the number found tuberculous.

Map III.; the areas containing farms which were inspected during the years 1906 and 1907 and those found tuberculous. In each of these maps the areas inspected are indicated, and those in which one or more tuberculous farms have been discovered are black. Several years have been grouped in order to obtain periods during which most of the farms in each district have been inspected. These maps demonstrate the considerable reduction that has taken place in the number of areas in which dangerous cows have been found during the 11 years.

F.—Number of tuberculous farms and cows in various regions and in various years.

To obtain this information I have divided the whole supply area into 11 latitudinal zones, defined in Table III. which gives in a condensed form the results analysed in the long tables not published in this report, but of which a small section has been reproduced in Table I.

(*a*) *Number of farms tested and found tuberculous during the* 11 *years.*

During the whole period of 11 years 1,385 farms have been tested. Of these 294 have been found to send tuberculous milk to Manchester on one or more occasions. In other words 21·2 per cent. of the farms supplying Manchester during the 11 years have, *at one time or another*, supplied tuberculous milk. It is difficult to estimate for how long the supply was infected each time that the presence of tubercle bacilli in the milk was detected, so that it is not possible to calculate exactly the amount of tuberculous milk sent to Manchester by these farms, but the amount must have been considerable.

(*b*) *Presence of cows with tuberculous udders on tuberculous farms.*

Of these 294 farms, 276 have been inspected once or several times during the period, and in 190 (or 68·4 per cent.) of the inspected farms the cow or cows to which the infection of the milk was due have

Table II.

Number of farms, number of cows on these farms, with the number of cows the milk of which was found to be infected with tubercle bacilli, in each of the 16-square-mile areas.

—	D.	E.	F.	G.	H.	I.	J.	K.	L.	M.	N.	O.	P.	Q.	R.	S.	T.
IX.[15]									3/45 0								
X.							2/47 0	5/86 42·9	**11/198 6**								
XI.	3/65 0			3/65 0			**12/266 0**	**13/288 3·7**	2/41 0								
XII.			2/27 0	3/62 0			6/120 15·8	4/82 32·8									
XIII.			1/48 100														
XIV.			1/20 0							1/10 0							
XV.				1/13 0			5/72 0	5/130 30			1/20 0						
XVI.									4/59 0								
XVII.						1/12 0		1/13 0	**54/901 20**	**21/295 13·5**							
XVIII.								2/30 0	**25/468 27·3**	**37/441 13·6**	1/9 0	1/12 0					

	D.	E.	F.	G.	H.	I.	J.	K.	L.	M.	N.	O.	P.	Q.	R.	S.	T.
XIX.						4/66 30·3		1/45 0	**9/151** **40**	2/38 ? ?	8/121 18·1	5/58 27·5					
XX.						**9/153** **19·5**	**7 174** **0**	**10/155** **35·1**	**23/401** **34·1**	**11/175** **44·5**	**21/341** **18·4**	**23/392** **17**	**11/155 ?** **33·5 ?**	2/20 ? 0			
XXI.						**16/334** **12·8**	**24/567** **46·3**	**47/982** **29·1**	**36/668** **32·9**	**57/1022** **38·3**	**18/277** **6·1**	**27/444** **21·8**	**17/277** **31·7**	3/43 0			
XXII.		1/45 0	**18/560** **53·9**	**36/981** **41·7**	**9/230** **43·2**	**6/191** **17/2**	**13/239** **61·5**	**28/515** **48·9**	**50/1077** **38·4**	**36/762** **40·8**	**19/284** **11·6**		**9/153** **7·1**	**22/337** **28·4**	**11/208** **18·2**		
XXIII.			2/52 ? 80·7 ?	**12/324** **62**	3/56 0	1/48 0		9/137 ? 48·9 ?	**10/218** **23·3**	**45/1030** **43·6**	**17/256** **28·5**		6/78 0	**25/400** **15**	**29/549** **35·5**	8/111 13·5	
XXIV.					1/120 0			**14/290** **38·6**	8/139 0	6/95 21	**21/409** **27·1**	**15/288** **8·3**	5/91 0	**22/460** **33**	**31/555** **22·7**	**9/154** **29·8**	1/10 0
XXV.					1/44 100	**6/154** **42·2**	**12/239** **66·9**	7/144 32·6		3/46 ? 0	**16/321** **24·6**	**16/266** **37·5**	2/49 0	6/99 0	**16/326** **25·1**		1/12 0
XXVI.					**7/218** **29·8**	**12/315** **45**	3/39 0	**13/295** **14·6**	2/54 97·4		4/73 31·5	**12/195** **0**	3/45 0		1/30 0		1/10 ? 0
XXVII.					1/9 0	**8/302** **35**		4/104 0		5/101 19·8	4/122 ? 56·5 ?	3/74 0	2/42 0				
XXVIII.		1/24 0	5/136 0	4/83 14·4	2/37 0	3/94 40·4										4/135 31·1	
XXIX.																	
XXX.								*a* *b* *c*									

15599 D

a/b
c

Explanation of the arrangement of the figures in each square :—

(*a*) Number of farms tested in each 16-square-mile area.
(*b*) Total number of cows in these farms.
(*c*) Number of cows, the milk of which was infected at one time or another, per cent. of the total number.
(The dark figures are in squares in which more than 150 cows were housed.)

been found. All these cows had tuberculous udders. After the elimination of these cows the milk of the farm almost invariably lost its infective properties. In 86 (or 31·6 per cent.) of the farms inspected the infecting cow had not been found up to the end of 1907.* This was in many cases proved to have been due (as I will show later) to removal of a diseased cow. The testing of samples and inspection have generally had the effect of causing the rapid disappearance of tubercle bacilli from the milk, *even when the diseased cows have escaped discovery.*

(*c*) *Number of cows on infected farms and amount of milk tested.*

The number of cows kept in the 1,385 farms was about 27,032, or an average of 19·5 per farm for the 11 years. The number of cows in farms the mixed milk of which was found to produce tuberculosis was 7,669. This figure is based upon data collected by the Veterinary Surgeons, at the time of their visits to infected farms, and may be accepted as accurate for all practical purposes.

The milk of 28·3 per cent. of all the cows supplying milk to Manchester has therefore *at one time or another* contained enough tubercle bacilli to produce tuberculosis in experimental animals. This figure is obviously not applicable to any single year.

(*d*) *Number of tuberculous farms at various times during the* 11 *years.*

In comparing various periods it was necessary to deal with a fairly large number of cows for each period. In order to get figures of comparable magnitude I have been obliged to group together all the farms tested during the years 1896 to 1900. The number of farms tested in each of the years 1896, 1897, 1898 was too small to reduce sufficiently the effects of hazard, and permit the results obtained during each of these years to be compared with those obtained in the following years. The actual state of the farms in 1896 was worse than the figures relating to the four years 1896 to 1900 indicate. (Samples of mixed milk were not examined during 1899.)

The number of farms tested and found tuberculous between 1896 and 1908 was as follows :—

Year.	Number of farms tested.	Number of farms tuberculous.	Number of farms tuberculous per cent. of farms tested.
1896–1900 (four years)	427	72	16·8
1901	368	44	11·9
1902	348	41	11·7
1903	339	44	12·9
1904	331	38	11·4
1905	571	48	8·4
1906	555	48	8·6
1907	549	40	7·2

The number of tuberculous farms has therefore been reduced by more than one-half.

* The infecting cows were in a few cases found during the year 1908. *See* page 406.

Table III.—Manchester Milk Supply 1896–1908.

Farms tested each year at the Laboratory by the examination of samples of milk collected at railway stations or at the farms found to supply tuberculous milk.

Latitudinal Zones from North to South.	Area in square miles over which the farms are spread.	1896–1900. Farms tested for the 1st time.		1901. Farms tested for the 1st time.		1901. Total No. of farms tested during the period.		1902. Farms tested for the 1st time.		1902. Total No. of farms tested.		1903. Farms tested for the 1st time.		1903. Total No. of farms tested.		1904. Farms tested for the 1st time.		1904. Total No. of farms tested.		1905. Farms tested for the 1st time.		1905. Total No. of farms tested.		1906. Farms tested for the 1st time.		1906. Total No. of farms tested.		1907 (a few 1908). Farms tested for the 1st time.		1907 (a few 1908). Total No. of farms tested.	
Each roman figures indicates one of the 4 miles broad latitudinal zones. Each capital letter indicates a 16-square-mile area. (*See* Maps.)		Total No. tested.	No. found tuberculous.	No.	No. found tuberculous. +	Total No	No. found tuberculous. +	No. tested.	No. tuberculous. +	No. tested.	No. tuberculous. +	No. tested.	No. tuberculous. +	No. tested.	No. tuberculous. +	No. tested.	No. tuberculous. +	No. tested.	No. tuberculous. +	No. tested.	No. tuberculous. +	No. tested.	No. tuberculous. +	No. tested.	No. tuberculous. +	No. tested.	No. tuberculous. +	No. tested.	No. tuberculous. +	No. tested.	No. tuberculous. +	No. tested.	No. tuberculous. +
IX. L																															
X. J, K, L																															
XI. D, G, K, L	192	5	—	0	—	0	—	11	1	11	1	4	—	8	—	12	3	18	3	13	1	30	1	17	—	39	—	7	—	39	1	69	6	8·6	6	3	50·0	1,392 (20·15)	105	7·5	190
XII. F, G, J, K																															
XIII. F																															
XIV. E, M																															
XV. G, J, K, N	192	55	8	2	—	19	1	0	—	2	—	3	—	3	—	4	—	5	1	13	—	18	1	15	1	22	2	4	—	20	1	96	14	14·5	14	9	64·2	1,593 (16·59)	313	19·6	209
XVI. L																															
XVII. I, K, L, M																															
XVIII. K, L, M, N, O ...	176	44	9	3	—	14	3	2	1	4	1	1	—	2	—	9	1	10	1	28	1	34	2	6	1	16	2	2	—	8	—	95	15	15·7	15	11	73·3	1,439 (15·4)	334	23·2	196
XIX. I, K, L, M, N, O ...																															
XX. I, J, K, L, M, N, O, P, Q ...	144	30	8	18	2	33	5	6	1	30	4	5	—	17	—	4	—	19	1	33	3	60	8	14	—	55	4	7	1	51	8	117	27	23·0	26	13	50·0	1,966 (16·8)	483	24·5	485
XXI. I, J, K, L, M, N. O, P, Q ...	144	81	14	21	3	71	10	19	—	73	9	26	2	86	9	15	3	59	10	52	4	147	9	14	1	120	12	17	—	135	5	245	57	23·2	50	38	76·0	4,614 (18·8)	1,417	30·4	1,266
XXII. E, F, G, H, I, J, K, L, M, N, O, P, Q, R.	224	105	18	34	3	94	11	26	2	91	8	18	4	87	20	21	3	92	11	23	4	125	17	21	—	111	8	10	—	105	8	258	76	29·5	73	49	67·1	5,582 (21·6)	2,162	38·3	1,326
XXIII. F, G, H, I, K, L, M, N, P, Q, R, S.	192	40	6	29	4	58	8	23	7	57	9	20	2	58	4	17	1	57	8	17	1	66	5	9	1	55	6	12	2	64	9	167	44	26·3	39	25	64·1	3,259 (19·5)	1,154	38·4	709
XXIV. H, K, L, M, N, O, P. Q, R, S, T.	176	28	3	25	3	38	4	18	1	38	3	14	—	48	5	15	1	41	3	10	—	42	2	16	—	59	4	7	1	50	2	133	20	15·0	19	13	68·4	2,611 (19·6)	591	22·6	460
XXV. H, I, J, K, M, N, O, P, Q, R, T.	176	21	3	11	—	18	—	3	1	10	1	6	3	14	4	9	—	14	—	5	—	18	1	21	4	42	7	10	—	33	2	86	16	18·5	15	11	73·3	1,700 (19·7)	432	25·4	251
XXVI. H, I, J, K, L, N, O, P, R, S	160	10	3	9	—	11	—	7	1	13	1	10	1	13	2	2	—	10	—	11	1	25	2	3	1	23	2	6	—	27	2	58	10	17·2	10	9	90·0	1,274 (21·9)	325	25·5	179
XXVII. H, I, K, M, N, O, P ...	112																														
XXVIII. E, F, G, H, I, J, S	112																														
XXIX. F, G, I	48	8	—	9	1	12	2	16	3	19	4	2	—	3	—	3	—	6	—	4	—	6	—	9	—	13	1	10	1	17	2	61	9	14·7	9	9	100·0	1,602 (26·2)	353	22·0	117
XXX. XXXI. D, C, Q	48																														
Totals for the whole area supplying milk to Manchester.	2,096	427	72	161	16	368	44	131	18	348	41	109	12	339	44	111	12	331	38	209	15	571	48	145	9	555	48	92	5	549	40	1,385	294	21·2	276	190	68·8	27,032 (19·5)	7,669	28·3	5,388
No. of tuberculous farms per cent. of farms inspected during each yearly period.		16·8		9·9		11·9		13·8		11·7		11·0		12·9		10·8		11·4		7·1		8·4		6·2		8·6		5·4		7·2											
No. of farms that had been previously inspected and No. of those found tuberculous.						207	28			217	23			230	32			220	26			362	33			410	39			457	35										
Percentage of tuberculous farms in this group.						13·5				10·5				13·9				11·7				9·1				9·5				7·6											

Summary of results during the 12 years 1896 to 1908.

Farms tested or inspected. Total No. of farms.	Farms found to supply tuberculous milk. No. of tuberculous farm.	Farms found to supply tuberculous milk. Tuberculous farm per cent. of total.	Total farms inspected. No.	Total farms inspected. No. in which tuberculous udder found.	Total farms inspected. Per cent.	Number of cows in farms tested. Total No. (average No. of cows per farm is given below the total No.).	Number of cows in farms tested. No. of cows on farms supplying tuberculous milk.	Number of cows in farms tested. Per cent.	Total No. of samples tested at the Laboratory.
1,385	294	21·2	276	190	68·8	27,032 (19·5)	7,669	28·3	5,388
Samples about which full particulars could not be obtained.									45
Total No. of samples tested for the Manchester Authority.									5,443

(*e*) *Recurrence of infection on certain farms.*

The infected farms have required close supervision. In Table IV. I have arranged the results of the tests in two groups so as to show first, the proportion of tuberculous farms among those tested for the first time each year; second, the results obtained in connection with farms which had been previously tested. The second group includes, therefore, all the farms which had to be frequently inspected because they had been found badly infected, or appeared specially liable to infection.

The *first group* contains (*a*) all the farms tested for the first time between 1896 and 1900 when things were at their worst; (*b*) farms tested for the first time after 1900 when farmers had become acquainted with the work done by the Corporation.

It will be seen that after excluding the results of the first years of inspection, the proportion of tuberculous farms has generally been a little higher among the farms previously inspected than among the farms inspected for the first time. In both groups a very marked and steady improvement is clearly shown.

TABLE IV.

Manchester Milk Supply, 1896-1908.

Farms tested each year.—1. *Tested for the first time;* 2. *tested again after having been previously tested.*

(In each case the actual number of farms found to supply tuberculous milk is given, as well as the number of tuberculous farms per cent. of the number of farms tested.)

	First group.			Second group.		
	Farms tested for the first time.			Farms previously tested.		
	Number of farms tested.	Number found tuberculous.	Per cent.	Number of farms retested each year.	Number found tuberculous.	Per cent.
1896–1900 ...	427	72	16·8	—	—	—
1901	161	16	9·9	207	28	13·5
1902	131	18	13·8	217	23	10·5
1903	109	12	11·0	230	32	13·9
1904	111	12	10·8	220	26	11·7
1905	209	115	7·1	362	23	9·1
1906	145	9	6·2	410	39	9·5
1907	92	5	5·4	457	35	7·6
	1,385	159	11·4	—	—	—

Total number of tests following a first test	2,103
„ „ first tests...	1,385
„ „ times the 1,385 farms were tested among them ...	3,488
Number of times farms were found tuberculous	294

(g.) *Unequal distribution of tuberculosis.*

A notable feature relating to the distribution of tuberculosis is brought out by Table III., as well as by Maps I., II., and III.

Tuberculosis is most prevalent in Zone XXII., which includes a large proportion of Cheshire farms and a comparatively small number of Derbyshire farms. *North of this zone* the proportion of tuberculous farms, though lower, is still high in Zones XXI. and XX., in which the farms are mostly Cheshire farms. Further north the proportion of tuberculous farms becomes much smaller, until in districts north of Burnley the percentage of tuberculous farms is reduced to less than one-third of that recorded in connection with Zone XXII. *South of Zone XXII.* there is also a marked reduction in the proportion of tuberculous farms, notwithstanding the fact that there are a few badly infected areas, but these are limited in extent. The reduction is not so marked as in the north. Mr. Brittlebank has informed me that in the districts where tuberculosis is most prevalent, there are many old farms, that much of the cattle is bred on the premises, and that the proportion of old cows is great.

In my opinion, based upon a considerable amount of evidence, these conditions favour infection and the extension of tuberculous lesions to the udder; possibly they are sufficient to account for the frequent infection of the milk in these districts.

(h.) *Gross results of the examination of samples of milk.*

To complete this brief statement I have prepared tables giving the results of the examination of milk coming to Manchester from various counties. The fact that an equal number of samples of the milk supplied by each farm has not been taken each year does not appear to affect the main results, which are in close agreement with those I have previously recorded regarding the number of tuberculous farms.

Table V.

Mixed milk arriving in Manchester from various counties between 1897 *and* 1908, *showing for each year number of samples examined, number found tuberculous, and percentage.*

(4,380 *samples taken at railway stations.*)

County.	1897.			1898.			1900.			1901.			1902.			1903.			1904.			1905.			1906.			1907.			1908.			Total.		
	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.
Cheshire	40	4	10·0	59	12	20·3	228	32	14·0	277	32	11·5	248	25	10·0	296	37	12·5	256	26	10·1	487	47	9·6	397	30	7·5	461	30	6·5	4	—	—	2,753	275	9·9
Derbyshire	2	2	100·	5	1	20·	82	3	3·5	103	5	4·8	126	9	7·1	82	7	8·5	103	13	12·6	125	6	4·0	111	6	5·4	83	3	3·6	1	—	—	823	55	7·5
Staffordshire.. ..	—	—	—	—	—	—	40	4	10·	47	2	4·2	32	1	3·2	39	6	15·3	37	1	2·7	56	4	7·1	109	8	7·3	91	8	8·9	2	—	—	453	34	7·5
Lancashire	1	—	—	—	—	—	4	1	25·0	2	—	—	8	1	12·5	11	1	9·0	15	1	6·6	70	2	2·8	54	2	3·7	57	2	3·5	1	—	—	223	10	4·5
Yorkshire	—	—	—	—	—	—	2	—	—	—	—	—	4	—	—	1	—	—	11	2	18·1	15	1	6·6	25	—	—	23	—	—	2	—	—	83	3	3·6
Shropshire	—	—	—	—	—	—	2	—	—	11	4	36·3	6	2	33·3	1	—	—	3	—	—	3	—	—	8	1	12·5	7	—	—	—	—	—	41	7	17·0
Wales and various..	2	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	4	—	—
Totals	45	6	13·3	65	13	20·0	358	40	11·1	440	43	9·7	424	38	8·9	430	51	11·8	425	43	10·1	757	60	7·9	704	47	6·6	722	43	5·9	10	—	—	4,380	384	8·7

Table V. shows :—

1st. *The actual number of samples of mixed milk examined yearly.* (These samples represent closely the milk actually supplied to the Manchester consumers.)

2nd. *The counties* from which the milk came.

3rd. The *number of samples found tuberculous.*

The number of samples examined during each of the years 1897 and 1898 is unfortunately too small for comparison. By throwing these two years together one gets a total of 110 samples, 19 of which were tuberculous, *i.e.*, 17·2 per cent.

No mixed samples were taken in 1899. The percentage of tuberculous samples for each of the 10 years is as follows :—

	Per cent.
1897–1898	17·2
1900	11·1
1901	9·7
1902	8·9
1903	11·8
1904	10·1
1905	7·9
1906	6·6
1907	5·9

It will be noticed that these figures agree closely with those relating to the number of tuberculous farms during the same periods. The reduction in the amount of tuberculous milk supplied to Manchester can therefore be fairly attributed to the reduction in the number of tuberculous farms. I have previously shown that the reduction in number of farms producing tuberculous milk was mostly, if not entirely, due to the *elimination of cows with tuberculous udders.*

Table V. also shows that the great bulk of the Manchester milk supply comes from Cheshire, and that the proportion of tuberculous samples was greatest in connection with that county. There has, however, been a great improvement in the milk coming from that source.

Table VI. deals with samples of unmixed milk. This table shows that of the 940 samples taken from udders which were thought by the veterinary surgeon to be possibly tuberculous, only 242 yielded milk capable of producing tuberculosis. This fact is particularly significant and should not be lightly dismissed.

Table VI.

Unmixed milk taken at the farms from cows with suspected udders.

(940 *samples.*)

County.	1896.			1897.			1898.			1899.			1900.			1901.			1902.			1903.			1904.			1905.			1906.			1907.			1908.			Totals.		
	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.
Cheshire ..	—	—	—	—	—	—	—	—	—	—	—	—	86	23	26·7	85	23	25·9	59	20	33·8	47	20	42·5	53	10	18·8	75	21	28·0	83	25	30·1	72	19	26·3	3	—	—	563	161	28·5
Derbyshire..	—	—	—	—	—	—	—	—	—	—	—	—	12	1	8·3	12	2	16·6	16	7	43·7	11	4	36·3	20	5	25·0	17	1	5·8	19	3	15·7	6	2	33·3	—	—	—	113	25	22·1
Staffordshire	—	—	—	—	—	—	—	—	—	2	—	—	13	3	23·0	10	1	10·0	1	1	100·	9	4	44·4	—	—	—	7	3	42·8	18	4	22·2	18	7	38·8	—	—	—	78	23	29·4
Lancashire..	7	—	—	17	3	17·6	3	—	—	17	3	17·6	31	4	12·9	55	7	12·7	5	1	20·	1	—	—	8	2	25·	7	2	28·5	5	1	20·	3	1	33·3	—	—	—	159	24	15·0
Yorkshire ..	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	1	25·0	2	1	50·0	—	—	—	—	—	—	—	—	—	6	2	33·3
Shropshire..	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	1	25·0	14	3	21·4	—	—	—	—	—	—	—	—	—	—	—	—	1	1	100·	—	—	—	19	5	26·3
Various ..	—	—	—	2	2	100·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	2	100·
Totals ..	7	—	—	19	5	26·3	3	—	—	19	3	15·7	142	31	21·8	166	34	20·4	95	32	33·6	68	28	41·1	85	18	21·1	108	28	25·9	125	33	26·4	100	30	30·0	3	—	—	940	242	25·7

In Table VII. *the total number of samples collected at the railway stations or at the farms is given with the results* of the examination. This table is given to facilitate the comparison of the results obtained in connection with the Manchester supply with those obtained in connection with other supplies as recorded in Table VIII.

Table VII.

General summary of the results of the examination of all the samples of milk received from the Manchester authority between 1896 *and* 1908.

—	1896.			1897.			1898.			1899.			1900.		
	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.
Railway samples	—	—	—	45	6	13·3	65	13	20·0	—	—	—	358	40	11·1
Farm samples...	—	—	—	—	—	—	38	5	13·1	44	3	6·8	12	6	50·0
Individual cows samples.	7	—	—	19	5	26·3	3	—	—	19	3	15·7	142	31	21·8

Table VII.—*continued.*

—	1901.			1902.			1903.			1904.			1905.		
	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.
Railway samples	440	43	9·7	424	38	8·9	430	51	11·8	425	43	10·1	757	60	7·9
Farm samples...	23	4	17·3	1	—	—	—	—	—	1	—	—	1	1	100·
Individual cows samples.	166	34	20·4	95	32	33·6	68	28	41·1	85	18	21·1	108	28	25·9

TABLE VII.—*continued.*

—	1906.			1907.			1908.			Totals.		
	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.	Total number of samples examined.	Number tuberculous.	Per cent.
Railway samples	704	47	6·6	722	43	5·9	10	—	—	4,380	384	8·7
Farm samples...	3	2	66·6	—	—	—	—	—	—	123	21	17·0
Individual cows samples.	125	33	26·4	100	30	30·0	3	—	—	940	242	25·7
Total ...	...	...	...	...	...	..	...	...	...	5,443	—	—

TABLE

General Summary of the results of the examination of samples of from various authorities

—	Total number of farms tested	Number found tuberculous.		1896-1900. Total number examined.	1896-1900. Number tuberculous.	1896-1900. Per cent.	1901. Total number examined.	1901. Number tuberculous.	1901. Per cent.	1902. Total number examined.	1902. Number tuberculous.	1902. Per cent.	1903. Total number examined.	1903. Number tuberculous.	1903. Per cent.
Blackburn	82. Average No. of cows per farm, 21.	9	R	—	—	—	3	0	0	3	1	33·3	4	0	0
			F	2	0	0	1	0	0	4	2	50·0	5	1	20·0
			C	5	2	40·0	5	0	0	4	0	0	3	0	0
Bristol	74. Average No. of cows per farm, 25.	4	R	50	2	4·0	16	1	0·2	2	0	0	—	—	—
			F	3	1	33·3	4	0	0	—	—	—	—	—	—
			C	—	—	—	—	—	—	—	—	—	—	—	—
Burton-on-Trent ..	117. Average No. of cows per farm, ?	19	R	—	—	—	—	—	—	—	—	—	—	—	—
			F	—	—	—	—	—	—	—	—	—	—	—	—
			C	—	—	—	—	—	—	—	—	—	—	—	—
Derby	155. Average No. of cows per farm, 16.	20	R	—	—	—	73	9	12·3	7	1	14·2	—	—	—
			F	—	—	—	28	4	14·2	—	—	—	—	—	—
			C	—	—	—	26	2	7·6	—	—	—	—	—	—
Salford	164. Average No. of cows per farm, ?	24	R	115	14	12·1	—	—	—	22	3	13·6	55	4	7·2
			F	—	—	—	—	—	—	—	—	—	—	—	—
			C	26	5	19·2	—	—	—	5	4	80·0	5	0	0
Sheffield	102. Average No. of cows per farm, ?	12	R	1	—	—	—	—	—	—	—	—	—	—	—
			F	7	—	—	—	—	—	—	—	—	—	—	—
			C	19	1	5·2	—	—	—	—	—	—	—	—	—
Various .. .. .. Counties of Linlithgow, Westmoreland, Lancashire, Cheshire, Yorkshire, Nottinghamshire, Warwickshire, Gloucestershire.	—	—	R	83	5	6·0	20	0	0	11	3	27·2	7	1	14·2
			F	12	2	16·6	2	0	0	4	0	0	6	0	0
			C	41	11	26·8	7	0	0	6	2	33·3	4	1	25·0
Total number of farms, excepting Various.	694. Average No. of cows per farm, based on available returns, 18.			364	43	11·7	185	16	8·6	68	16	23·5	89	7	7·8
Mixed samples only .. (Yearly totals and percentages.)				249	21	8·2	112	10	8·9	45	8	17·7	66	5	7·5

R = Railway stations samples. F = Farm mixed

VIII.

mixed and unmixed milk received at the Public Health Laboratory (1896–1908). (1,557 *samples.*)

1904.			1905.			1906.			1907.			Mixed milk collected at railway station or in road.			Mixed milk collected at the farm.			Unmixed milk from individual cows.			Total number of samples of milk examined.
Total number examined.	Number tuberculous.	Per cent.	Total number examined.	Number tuberculous.	Per cent.	Total number examined.	Number tuberculous	Per cent.	Total number examined.	Number tuberculous.	Per cent.	Total number examined.	Number tuberculous.	Per cent.	Total number examined.	Number tuberculous.	Per cent.	Total number examined.	Number tuberculous.	Per cent.	
2	0	0	13	0	0	30	0	0	19	2	10·5	74	3	4·0							
10	1	10·0	2	0	0	2	0	0	16	2	12·5				42	6	14·3				
4	2	50·0	8	2	25·0	5	0	0	11	1	9·1							45	7	15·5	161
—	—	—	—	—	—	—	—	—	—	—	—	68	3	4·4							
—	—	—	2	0	0	—	—	—	—	—	—				9	1	11·1				
—	—	—	—	—	—	—	—	—	—	—	—							—	—	—	77
30	6	20·0	37	4	10·8	29	7	24·1	44	3	6·8	140	20	14·2							
11	0	0	44	2	4·5	26	1	3·8	17	2	11·7				93	5	5·1				
25	5	20·0	23	4	17·3	16	8	50·0	12	4	33·3							76	21	27·6	314
—	—	—	—	—	—	—	—	—	84	10	11·9	164	20	12·1							
—	—	—	—	—	—	—	—	—	10	1	10·0				38	5	13·1				
—	—	—	—	—	—	3	0	0	29	7	24·1							58	9	15·5	260
18	2	11·1	9	0	0	29	2	6·8	—	—	—	248	25	10·0							
—	—	—	—	—	—	—	—	—	—	—	—				—	—	—				
5	1	20·0	—	—	—	7	1	14·2	—	—	—							48	11	22·9	296
—	—	—	—	—	—	46	5	10·9	23	1	4·3	70	6	8·5							
—	—	—	3	2	66·6	1	1	100·0	1	0	0				12	3	25·0				
—	—	—	5	3	60·0	4	3	75·0	6	1	16·6							34	8	23·5	116
7	0	0	12	2	16·6	13	0	0	23	2	8·6	176	13	7·3							
—	—	—	—	—	—	—	—	—	6	0	0				30	2	6·6				
6	0	0	13	1	7·6	9	1	11·1	14	2	14·2							100	18	18·0	306
118	17	14·4	171	20	11·6	220	29	13·1	315	38	12·0	940	90	9·5	229	22	9·6	361	74	20·4	1,530
																		Unsuitable samples		..	27
																					1,557
57	8	14·0	71	6	8·4	147	14	9·5	193	18	9·3	940	90	9·5							

samples. C = Cows unmixed samples.

i.—Gross results of the examination of samples of milk for various authorities.

Table VIII.—*The results of the examination of* 1,530 *samples of milk received from Salford, Blackburn, Bristol, Burton-on-Trent, Derby, Sheffield, and several other places in England and Scotland* cannot be compared in detail with those obtained in connection with the Manchester supply.

1. The *number of samples* examined each year for each authority is not sufficient for statistical purposes.

2. The *work was not conducted continuously* nor according to the same plan in each place through the whole period, and I had not the means, which were afforded to me in Manchester, of comparing accurately the results of the veterinary inspection of the farms with those obtained at the Laboratory.

The *samples of mixed milk represent for each district or group of districts, the milk sold to the consumer.*

The results of the examination of unmixed milk do not indicate the state of the milk supply but of the cows individually tested.

The discovery of tuberculous udders is influenced by two important factors, viz.:—

1. The frequency of advanced and easily detected lesions; 2, the skill of the Veterinary Inspector. The skill of the Veterinary Inspector is indicated less by the number of diseased udders which he detects than by the number of tuberculous farms which become free from tuberculosis after the removal of the infected cows which he has selected for bacteriological examination and which are ultimately proved to be tuberculous by the experimental tests.

It is to the mixed milk only that I will refer in the following remarks.

Some of the towns entered in Table VIII. are supplied by the same districts as, or by districts contiguous to, those supplying Manchester.* The *Salford* milk supply area coincides very closely with the Manchester area. A fairly large number of farms send milk to both towns.

Blackburn is supplied by districts which also supply Manchester and Salford, and I have previously shown that the milk coming to Manchester from that part of Lancashire is much freer from tubercle bacilli than the milk produced in other districts.

Derby takes its milk mostly from the southern part of Derbyshire, an area which is contiguous with the part of the county supplying Manchester and Salford.

Sheffield is supplied by the southern parts of the West Riding of Yorkshire, and the northern half of Derbyshire; this area is contiguous with that supplying Manchester.

Burton-on-Trent gets most of its milk from parts of Staffordshire. which also supply Manchester.

The *Bristol* milk area is quite distinct from the preceding ones, and is situated in Gloucestershire and Somersetshire.

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* It is obvious that my remarks are based only upon what has come within my knowledge through the examination of samples sent to my Laboratory.

k.—Comparison of the results obtained in various places.

Although the samples of mixed milk received from these various places during the 11 years were comparatively few in number, they have yielded results which are not without interest, as is shown by the following figures.

TABLE IX.

Results of the examination of samples of mixed milk collected in various towns.

Town.	A. 11 years.		B. 2 years, 1906–7.	
	No. of mixed milk samples examined in 11 years.	No. tuberculous—per cent., average for 11 years.	No. of samples examined in 1906–7.	No. found tuberculous—per cent., 1906–7.
Blackburn	74	4·0	49	4·0
Sheffield	70	8·5	49	8·1
Derby (1901–8)	164	12·1	84	11·8
Burton-on-Trent (1904–8) ...	140	14·2	73	13·6
Bristol	68	4·4	No examinations.	
Salford	248	10·0	29	6·8
Manchester	4,380	8·7	1,426	6·3
Various counties* from Scotland to the south of England.	176	7·3	36	5·5

* The figures relating to this group cannot be compared with those above. During the first few years the samples came chiefly from the neighbourhood of Manchester; in the last two years the samples have come chiefly from districts where tuberculosis was less prevalent.

These figures are in agreement with those obtained in connection with the Manchester supply and which show that in the zone including Cheshire and Derbyshire, tuberculosis was very prevalent during the period under consideration, north and south of that zone the disease was much less prevalent, except in limited districts such as the one from which Burton-on-Trent obtains its supply. The same figures also show that the well sustained and very systematic effort made by Manchester to purify its milk supply has been more effectual than the work done in other places. It must be noticed that the figures given in the above table do not show the actual improvement which has taken place in the course of the 11 years, but only how much the average of the last 2 years is below the average for the last 11 years. As the number of yearly samples taken in Manchester during the last 6 years was very much greater than during the previous 6 years, and as a great improvement had already taken place at the end of the first 6 years, it is clear that the Manchester average for the 11 years given above is lower than if an equal number of samples had been taken each year.

The effect of the working of the Manchester clauses is better shown by comparing the state of the milk supplied from the same (or contiguous) districts to Manchester and to other towns during the last two years. (Two years are taken in order to obtain a sufficient number of samples in certain cases so as to reduce errors.)

TABLE X.

Samples of mixed milk coming from various districts, collected in Manchester and four other towns, in 1906 *and* 1907, *and the number found tuberculous per cent. of the number of samples tested at the Laboratory.*

Milk-supplying Counties.	Town supplied.	Samples of Mixed Milk tested in 1906 and 1907.	
		No.	Number found tuberculous, per cent.
Lancashire	Manchester	111	3·6
	Blackburn	49	4·0
Derbyshire	Manchester	194	4·6
	Derby	84	11·9
Derbyshire and Yorkshire (adjacent districts).	Sheffield	69	8·6
Staffordshire	Manchester	165	7·2
	Burton-on-Trent ...	73	13·7

These figures indicate, first, that even where tuberculosis was not very prevalent, as in the Blackburn district, efficient supervision has brought about a sensible reduction in the amount of tuberculous milk supplied to Manchester.

Second, that where tuberculosis was very prevalent the proportion of tuberculous milk supplied to Manchester has been reduced to nearly half of what it has in other towns supplied by the same or contiguous districts.

VII.—*A.* Evidence obtainable as to the Source of Tubercle Bacilli from the Bacteriological Examination of the Milk and the Inspection of the Farms.

To estimate the value of this evidence it is necessary to realise that there are very few, if any, herds in this country free from tuberculosis. There are a few farms which are kept free by periodical testing, elimination of tuberculous animals, and non-admission of reacting cattle, but these farms are so few that they do not materially affect the general state of things.

One can say without exaggeration that there are very few herds of more than 10 cows that do not include one or more tuberculous cows. This general statement is partly based upon information which I have received from various quarters respecting the results obtained with regard to several herds tested with tuberculin. It is also based upon the personal experience which I gained in 1897, 1898, and 1899, while testing experimentally the value of tuberculin by means of four small herds (two in Lancashire and two in Cheshire). The total number of cows or heifers tested was 128; the animals giving a positive reaction were slaughtered and examined post mortem. It was found that 37, *i.e.*, 30 per cent., of these cows were tuberculous. The percentages for each farm were respectively

100 per cent., 32 per cent., 17 per cent., and 25 per cent. On comparing these results with those obtained, shortly after, in Aberdeen, I found that there was a remarkable agreement. 240 heads of cattle were tested with tuberculin before being slaughtered at the abattoir. Among these animals were 137 heifers or cows, of which 52, or 37 per cent., were found tuberculous. Very similar results were obtained by the same method as far back as 1891 by Lydtin in the Duchy of Baden. This observer found that out of 110 head of cattle 37 were tuberculous. There is a remarkable agreement in the results obtained in these three places so distant from each other. These results would almost justify one in assuming that one out of every three cows is tuberculous, but taking account of the unequal distribution of the disease, and of the effect of age (*see* page 395), it seems safer not to assume a greater proportion than the one I have assumed for purposes of argument.

I can therefore say, without exaggeration, that out of the 1,385 farms inspected on behalf of the Manchester authority there were probably at least 1,300 with tuberculous cows, and to exclude any fear of exaggeration we may reduce this number to 1,000; it is safe to assume that on each of these farms there were, on an average, several tuberculous cows. The milk supplied by these farms has frequently been tested bacteriologically, with the result that 294 of them were found to supply tuberculous milk. In consequence of this 276 farms were inspected, and in 190 of them the veterinary surgeon, *with the help of the bacteriologist*, was able to discover one or more cows with tuberculous udders. After the removal of those cows the milk generally ceased to produce tuberculosis in guinea-pigs when examined on one or more occasions afterwards.

Probably in the majority of cases, the milk was tuberculous owing to the presence on the farm of a cow or cows with tuberculous udders. There remained, however, a fairly large number of cases (a little less than one-third of all tuberculous farms) where the source of infection could not be established in this simple fashion, and in order to obtain more information about this doubtful group I have classified the farms belonging to it according to the results of the bacteriological tests and of the visits of inspection. I then asked Mr. Brittlebank to furnish me with the history of all the farms in relation to which the results did not seem to have been satisfactory or clear.

The classification of results which I adopted for the purpose of clearing the obscure points, or to test the value of the results, will be made clear by a reference to the detailed record of results given in Table I. (page 383).

B. Analysis of the Results of Bacteriological Examinations.

Table I., as has been previously explained, shows the results of the examinations of milk made each year in connection with each farm. All the results relating to one farm are entered on one line; the order in which the samples have been taken at the railway station and at the farm, as well as the results of the examination, are indicated as explained at page 384.

The 16-square-mile area to which this section of the table corresponds (XXI. M.) was one of the most difficult to deal with, and I have selected it as giving good examples of nearly all the combinations of

events that have been observed during the 12 years in the various districts dealt with. The results obtained may be classified as follows :—

* *Evidence indicating the reliability of bacteriological examinations and the importance of tuberculous udders as source of tubercle bacilli.*

1. *Repeated examinations of railway samples with uniform negative results.*

A. Repeated examinations at short intervals during the same year. (Example, Table I. 84/50 (2*a. b.*) $\frac{0\,0\,0\,0}{}$ 4 samples in 1903 and in 1905, each.)

The milk of a number of farms was tested more than once *in the same year* with negative results :

Twice in great many cases.
Three times in about 79 cases.
Four „ „ 10 „
Five „ in 1 case.
Six „ in 2 cases.

B. Repeated examinations in the course of several consecutive years.

There were over 72 farms which gave invariably negative results once and usually twice a year for at least five consecutive years. In a much greater number of cases similar results were obtained for two, three, or four consecutive years.

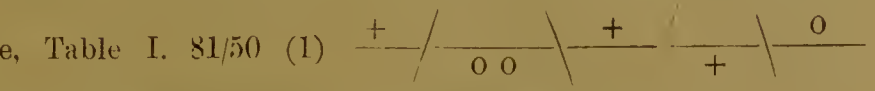
C. The value of the above results was controlled in connection with 17 farms in the following way. The railway samples having given negative results, the farm was visited and samples of unmixed milk taken from all the cows which showed signs of some disease. The results of the examination of the unmixed milk agreed with those obtained with the mixed milk ($\frac{0\,0\,0}{0\,0\,0\,0}$ No example in Table I.). In some cases the samples were taken simultaneously at the railway station and at the farm.

2. *Simultaneous examination of mixed milk and of unmixed milk from the same farm with positive results.* (Example, Table I. 84/51 (4) $\frac{+}{}\!\!\diagup\!\!\diagdown\frac{+}{+\,+}\!\!\diagup\!\!\diagdown\frac{0}{}$ 1901.) I have some 20 records of this kind. They show, as well as the controls in negative cases, that it is possible to estimate the state of a herd by the examination of mixed samples of milk.

3. *Railway samples of mixed milk being found tuberculous the farm is visited, and at least one cow with tuberculous udder is found among those with diseased or suspicious udders.* (Example, Table I. 82/52 (1*a. b.*) $\frac{+}{}\!\!\diagup\!\!\diagdown\frac{}{0\,0\,+}\!\!\diagup\!\!\diagdown\frac{0\,0}{}$ 1906.) This sequence was observed in the case of 190 out of the 276 farms visited, *i.e.*, in 68·8 per cent. of the cases.

Sometimes the tuberculous cow was not found at the first visit and the railway milk remained tuberculous. A cow with tuber-

culous udder was found and removed on the second or third visit; the railway milk was afterwards found free from tubercle bacilli.

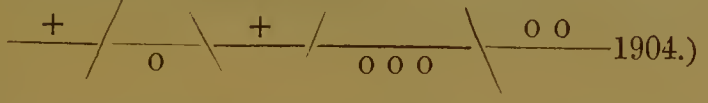
(Example, Table I. 81/50 (1) 

1906.) I have records of some 16 occurrences of this kind.

From the above evidence it follows that the appearance of tubercle bacilli in the milk of a herd was associated, on the occasions when the examinations were made, in at least 68·8 per cent. of the cases, with the presence of one or more cows with tuberculous udders in the herd.

There must have been *many tuberculous cows in herds yielding milk free from tubercle bacilli*, and the milk from these herds must have been exposed to various other chances of tuberculous infection. Yet several examinations, sometimes at very short intervals, failed to show in such cases any clear evidence of intermittent infection.

* * *Evidence regarding cases in which the source of infection of the milk was not discovered.* (Example, Table I., 84/50 (3)



There were 86 farms (31·1 per cent.) in which the veterinary inspector was unable to find the cow or cows producing tuberculous milk. In 80 of these cases (although the cause of infection had not been detected) the visit of inspection was followed by *disappearance of tubercle bacilli from the mixed milk.* The other six cases belong to a group of farms which I will discuss when dealing with continued infection. I have no further information regarding 20 of these farms, either because Mr. Brittlebank could not obtain any reliable data or because the farmers refused absolutely to give him any information (this occurred in three cases only). This leaves 60 cases for investigation, and from the histories obtained by Mr. Brittlebank I have been able to classify them as follows :—

1. The farmer had *sold one or more cows between the day of collection of the railway sample and that on which the farm was visited.*

This was found to have certainly taken place in 32 cases. In six of these the farmer admitted that he had sold a cow with a diseased udder shortly before the visit.

In five the cow was diseased, but no information was available regarding the state of the udder.

In 21 the state of the cow could not be ascertained.

In addition to these 32 cases, there were eight more cases of farmers or dealers who were constantly buying or selling cattle. Sale was going on at three of these farms at the time of the veterinary visit. There were therefore, in all probability, 40 out of the 60 farms in which the composition of the herd had altered by the removal of cows between the taking of the railway sample and the visit to the farm. Cows that were admittedly diseased had been removed from 11 of these farms.

2. *The farmer had sent to town milk purchased from a neighbouring farm.*

This was fully established in five cases, and had probably occurred in others.

In three out of the above five, the purchased milk came from a farm where a cow with tuberculous udder was found.

3. *There was a tuberculous udder on the farm but this had not been found before the end of the period under investigation.*

In four cases the cow with tuberculous udder was found in 1908.

In one case samples were taken from suspicious cows and these samples gave negative results on being examined bacteriologically, but there was another cow with advanced tuberculosis and indurated udder, from which no milk could be obtained at the time. In Mr. Brittlebank's opinion the udder of that cow was certainly tuberculous and had, previous to the visit, been the source of infection.

4. *In 10 instances the farmer denied having sold any cow or bought any milk* from his neighbours, but in no less than three of these cases there was ground for not accepting the information as correct.

Of the 60 cases investigated there are several which should have been included among those in which the infection of the milk had been clearly traced to a tuberculous udder.

	Cases.
Late discovery of the udder	5
Obtaining tuberculous milk from a neighbouring farm where there was a cow with tuberculous udder	3
	8

It is almost certain that the selling of cows between the collection of a railway sample and the visit to the farm accounts in many cases for the disappearance of tubercle bacilli from the milk on the second occasion; this had taken place certainly in 32 cases, and almost certainly, in eight more cases, giving a total of 40. In two more cases milk had been purchased from a neighbour, but as the state of the cows on the neighbouring farm was not ascertained, it is not possible to say what was the cause of infection.

The source of tubercle bacilli in 50 of the cases in question was therefore :—

	Cases.		Per cent.	
Certainly a cow with tuberculous udder either on the farm or on a neighbouring farm in ...	8	or	13·3	
In all probability a cow with tuberculous udder in	11	„	18·3	31·6
Probably a cow removed from the farm in	29	„	48·3	
Possibly a cow on a neighbouring farm in	2	„	3·3	51·6
	50	„		83·2

This leaves only 10 cases entirely unexplained or 16·7 per cent. The 86 cases in which the cause of infection of the milk was not found in the usual way may be therefore divided proportionally to this percentage as follows :—

Cases in which the cause of infection was certainly or almost certainly a diseased udder	say	27
Cases in which the cause was probably a diseased cow	„	44
Cases in which the infection has remained without explanation	„	15
		86

By introducing these figures into the general statistics the following estimates are obtained :—

Farms producing tuberculous milk and in which tuberculous udders were found directly ...	190	
Farms producing tuberculous milk and in which tuberculous udders were found late or indirectly	27	
		217
Farms producing tuberculous milk and in which there were probably tuberculous udders ...		44
Farms producing tuberculous milk and in which nothing has been found to explain infection ...		15
		276

This gives the following general percentages :—

	Per cent.
Tuberculous udders the cause of infection ...	78·6
Tuberculous udders probably the cause of infection	16·
Nothing definite found to connect infection with the state of the cow	5·2
	99·8

If, instead of averaging the results obtained in connection with the whole supply area one takes into consideration only those obtained in the 16-square-mile areas, in which the number of farms *inspected* exceeded five and where, therefore, the number of farms and cows was sufficiently large to form a satisfactory basis for a statistical investigation, a striking difference is revealed between the farms which were sufficiently close to Manchester to permit of rapid inspection, and those less accessible. This difference is brought out in Table XI.

Table XI.

Effects of the Distance of the Farm upon the Results of Inspection.

Proportion of tuberculous cows with tuberculous udder found in each of the 16*-square-mile areas in which the number of farms inspected numbered five or more* (17 "16*-square-mile areas*").

Reference to the 16-square-mile areas.	Total number of farms sending milk to Manchester.	Aggregate number of cows on these farms.	Number of farms inspected.	Number of farms on which tuberculous udders were found.	Number of farms with tuberculous udders, per cent. of farms inspected.
XVII. L ...	42	721	8	7	87·5
XVIII. L ...	25	468	5	4	80·
XX. L ...	23	401	7	6	85·7
XXI. J ...	24	567	7	4	57·1
K ...	47	982	11	7	63·6
L ...	36	668	8	8	100·
M ...	57	1,022	15	14	93·3
Farms within 16 miles of Manchester averages.	(254)	(4,829)	(61)	(50)	(82·)
XXII. F ...	18	560	7	3	42·8
G ...	36	981	12	9	75·
J ...	13	239	6	5	83·3
K ...	28	515	11	8	72·7
L ...	50	1,077	13	10	76·9
M ...	36	762	12	5	41·6
XXIII. G ...	12	324	6	3	50·
M ...	45	1,030	13	8	61·5
R ...	29	549	8	5	62·5
XXIV. Q ...	22	460	5	3	60·
Farms more than 16 miles from Manchester.	(289)	(6,497)	(93)	(59)	(63·)
General Totals	543	11,326	154	109	Over 70·

N.B.—Manchester is situated in the latitudinal zones XVII. and XVIII. at the place where they are crossed by the longitudinal zones L and M. It is clear that the proportion of cases in which the veterinary surgeon was able to discover cows with tuberculous udders on farms sending tuberculous milk to Manchester is greater in connection with the farms which were easy of access and could be inspected rapidly, than with the other farms.

It does not appear desirable for the present to attempt to push the analysis of these cases further. Two facts, however, remain clear, viz. :—

(1) The occurrence of tubercle bacilli in milk sent to town was due to the presence of tuberculous cows with tuberculosis of the udder in about three-fourths of the cases.

(2) The farmer must have had in most of the remaining cases some knowledge of the probable source of infection, for after he had possibly become acquainted with the fact that his milk was being tested the tubercle bacilli disappeared. The frequency of this occurrence renders accidental coincidence improbable.

Diagram III.

Incidence of Tuberculosis in Cattle of various ages.

Author's analysis of the results obtained in Aberdeen on the basis of Tuberculin tests and post-mortem examinations.

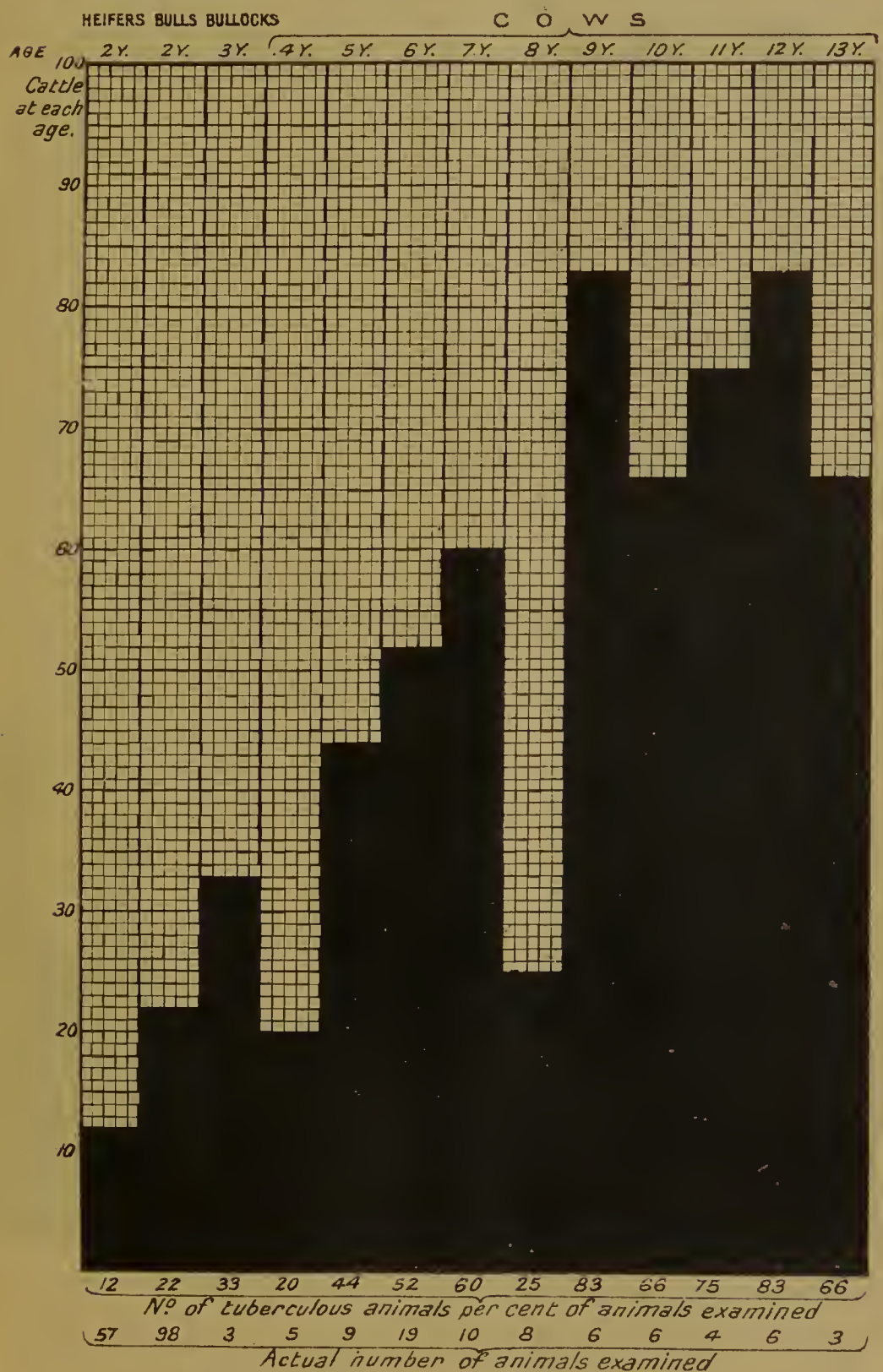


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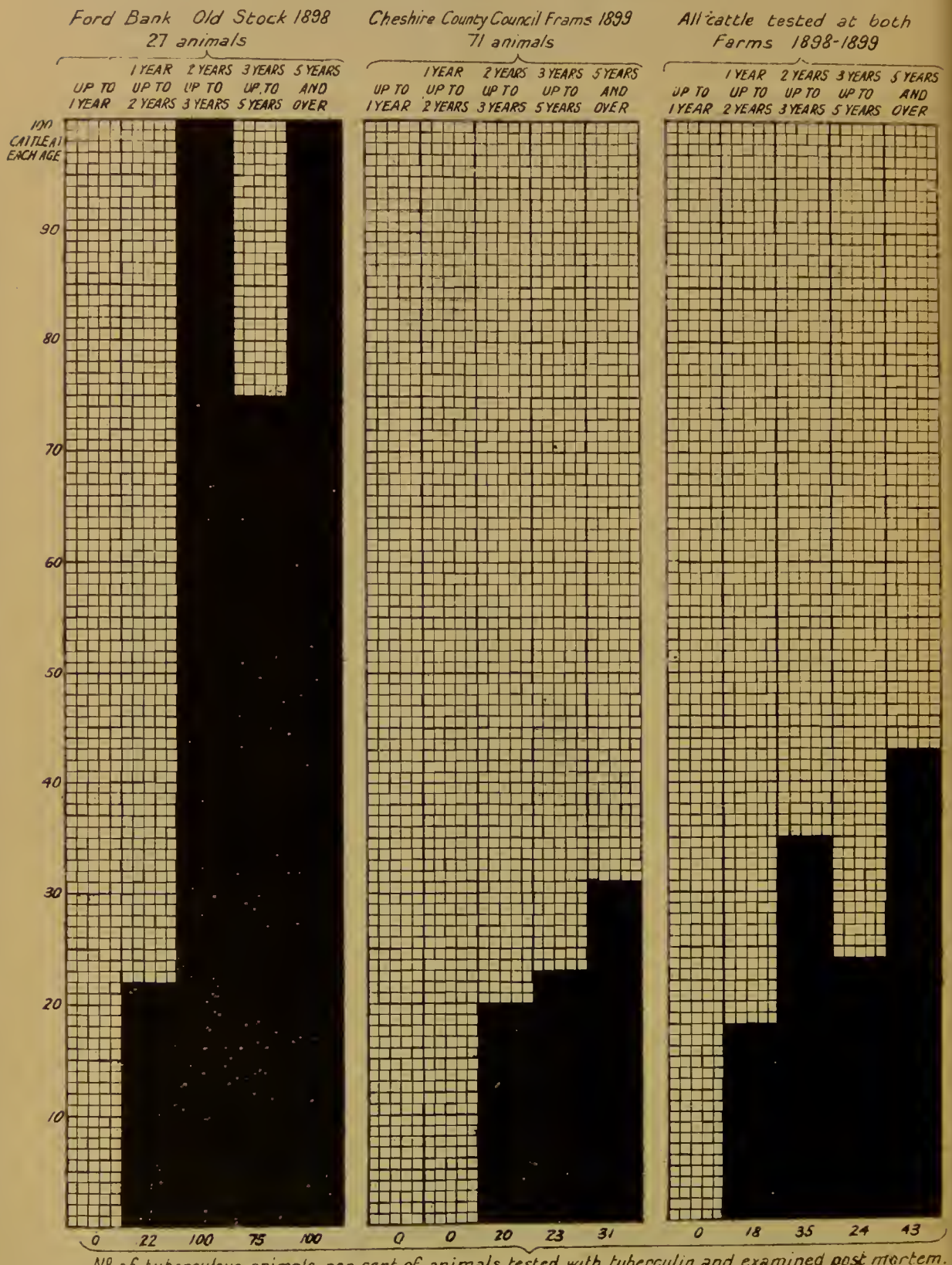
Diagram IV.

Incidence of Tuberculosis in Cattle at Various Ages.

(2 small herds) 128 animals



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With regard to the source of the tubercle bacilli in 5·2 per cent. of the cases it would not be safe to say that the source was not the udder and *must therefore be one of the other causes previously mentioned.* I have already pointed out that in nearly one-third of these cases Mr. Brittlebank had reasons to doubt the truth of the information given to him regarding the movements of the cows or the source of the milk.

*** *Persistence of tubercle bacilli in the milk of some farms under supervision.*

In all the cases which have been discussed so far, whether the source of infection of the milk was discovered or not, the results of supervision were satisfactory. There have, however, been instances of failure, apparent or real. In about 38 of the farms inspected during the 12 years the railway milk was found repeatedly tuberculous. This sometimes happened for 2, 3, or 4 years in succession. More frequently there was an interval of one or more years between the occurrences. The information which I obtained from Mr. Brittlebank regarding these farms suggests that the persistent infection of the milk was, in the majority of cases, due to errors on the part of the farmer.

The conditions observed in connection with these farms may be roughly grouped as follows :—

	Farms.
Many old cows kept on the farm (in several cases all the stock had been reared on the farm)	16
Bad housing, inferior stock, premises dirty	8
Frequent buying and selling, stock changing frequently	3
Buying at low prices any class of cow	2
Change of tenants and of herd	3
Purchase of cows apparently good, but found tuberculous shortly afterwards	2
Taking suspicious cow from another farm	1
No explanation (in two cases the tuberculous cows were young)	3
	38

It would appear therefore that the most important cause of difficulty was the presence on the farms of old milk cows. Many of these cows were undoubtedly tuberculous, and as they became older they, one after the other,. developed lesions of the udder as the disease advanced.

The frequency of tuberculosis in aged cows is well known, and is made evident by Diagram III. based on statistics collected in Aberdeen in 1899 by J. MacLauchlan Young and J. I. Walker, and Diagram IV., which is based on statistics collected by myself in Manchester during the years 1898–1899. The two investigations were quite independent, and were made to ascertain the value of tuberculin in diagnosis, but I have utilised them here to determine the age incidence of tuberculosis.

The buying of new cattle or changes in the composition of the herds introduce difficulties which, from an administrative point of view, are serious, and indicate the necessity of close, frequent and skilful supervision. This cause accounts for 10 cases of recurrence

Bad housing, inferior stock and dirt, which were noticed in eight cases, cannot account in themselves for tuberculous infection, but they undoubtedly favour its spread and render supervision and the application of preventive measures more difficult.

*** *Sudden appearance of tubercle bacilli in the milk supplied by farms that had been supervised for several years and had always supplied milk free from tuberculosis.*

The unexpected appearance of tubercle bacilli in the milk produced on farms under supervision and which for several years had supplied non-tuberculous milk was due to circumstances very similar to those which caused recurrence of infection on certain farms. The special conditions observed were as follows :—

	Farms.
Old cows kept (in most of these farms an old cow was found with a tuberculous udder)	26
Cows purchased and found tuberculous soon after purchase	3
Frequent buying and selling, stock changing frequently	2
Bad housing, inferior stock, dirty premises	3
Tuberculous udder unintentionally overlooked by farmer	1
No definite information (in one case the diseased cow was young. In some instances close breeding for high milking was supposed to be of importance by the farmer)	15
	50

In the great majority of cases a cow with tuberculous udder was found, and with very few exceptions the cow was an old one.

This group of cases shows specially the value of *constant supervision* and good administrative methods. The fact that milk coming from these farms had been free from tuberculosis was no guarantee that tuberculosis might not occur at any moment. This was to be expected, for there were undoubtedly many tuberculous cows on these farms. There was a probability of the farmers buying from time to time a tuberculous cow, for they are nearly all adverse to the use of tuberculin, which is the only reliable test for the diagnosis of early tuberculosis.

*** *Farmers who have ceased sending milk to Manchester.*

The number of farmers who have ceased sending milk to Manchester since the milk clauses came into operation, is not considerable.

Fourteen have ceased although their milk had not been found tuberculous. Eighteen have ceased after the milk had been found tuberculous. In four cases the supply was discontinued owing to removal or death. This list is probably not complete, but is sufficient to show some of the effects of the work done in Manchester. One of the farmers included in this list had to cease owing to a compulsory order. The others as far as I know ceased voluntarily, and probably send their milk elsewhere, or, as two of them did, took to cheese making.

Before concluding this report I desire to express my great indebtedness to various gentlemen who have supplied me with the information which I required in order to complete the data relating to samples of milk examined in my laboratory. I wish specially to mention here the valuable assistance which I have received from Dr. C. H. Tattersall of Salford, Dr. W. J. Howarth of Derby, Dr. H. Scurfield of Sheffield, Dr. D. S. Davies of Bristol, Dr. J. M. Cowie of Burton-on-Trent. I have in several places alluded to Dr. James Niven's important share of the work done in Manchester, and to the assistance I have frequently received from Mr. Jas. King, Mr. A. Holburn, Mr. J. S. Lloyd and Mr. J. W. Brittlebank, who have successfully acted as veterinary inspectors for Manchester. To the work done by various members of my laboratory staff I have referred in the text. I wish, however, to acknowledge more specially the considerable help which I have received from Dr. E. J. Sidebotham and Dr. A. Sellers.

General Summary and Conclusions.

1. Between the years 1896 and 1908, 5,320 samples of mixed milk coming from 12 different counties have been tested bacteriologically at the Laboratory, and 474 of these samples have produced tuberculosis in experimental animals. In other words, 8·9 per cent. of the mixed milk (*i.e.*, milk as supplied to consumers) contained a sufficient number of tubercle bacilli to produce tuberculous infection.

2. A certain proportion of the milk coming from each of the counties was tuberculous. No region appeared to be entirely free from bovine tuberculosis, but the extent to which the milk was affected varied considerably according to the region from which it came. The differences were considerable. The proportion of tuberculous samples coming from North Lancashire, the North Western districts of Yorkshire, and the parts of Gloucestershire and Somersetshire supplying Bristol, was on an average for the 12 years from 4 to 4·4 per cent.

The proportion for	Cheshire	was	...	...	9·9	per cent
„	„	„	Derbyshire	„ from	7·5 to 12·1	„
„	„	„	Staffordshire	„ „	8·9 „ 14·2	„

These figures are not based upon the examination of equal numbers of samples in each case, but they are nevertheless significant.

3. Their significance is made clearer by the fact that the Manchester Sanitary Authority has, by means of the Manchester Milk Clauses, succeeded in reducing the amount of tuberculous milk supplied by one of the most infected counties from 16·1 per cent., which was the proportion in 1897–1898, to 6·5 per cent. in 1907. The great prevalence of bovine tuberculosis in certain districts is therefore clearly due to avoidable or preventable causes.

4. It is now generally accepted that so far as man is concerned, the chief danger connected with bovine tuberculosis is due to the presence of tubercle bacilli in cow's milk.

It is obviously desirable from every point of view to eradicate completely bovine tuberculosis. Unfortunately agriculturists have not, as a rule, fully realised the necessity of dealing with this problem. But as bovine tuberculosis is a serious danger to the health of man,

it is the duty of the Public Health Authorities to prevent the distribution of milk capable of conveying tuberculosis.

5. The evidence summarised in this report shows clearly that the milk becomes certainly infectious when tuberculous lesions are present in the udder.

6. In cases of tuberculosis without *clear* affection of the udder there may also be occasional infection of the milk. There is a difference of opinion as to whether the appearance of tubercle bacilli in the milk is evidence of the onset of mammary lesions, or may occasionally be entirely unconnected with mastitis. There is however no difference of opinion as regards the danger of infection of the milk in all cases of advanced tuberculosis; in such cases the udder is either diseased or liable to become diseased at any moment.

7. Lesions of the udder were found in one or more of the cows on at least three-fourths of the farms supplying tuberculous milk to Manchester.

8. That tuberculous udders were not found more often was, in all probability, due to the slowness of bacteriological methods, or to the distance of farms from the administrative centre which prevented rapid administrative action. This, not unfrequently, allowed the farmer to remove one or more tuberculous cows from his farm. There are good reasons to believe that this had taken place at 16 per cent of the farms supplying tuberculous milk.

9. The general outcome of the facts collected by me during the 11 years under consideration is that the infection of the milk was—

Certainly or almost certainly due to tuberculosis of the udder at	78·6	per cent. of the farms.
Probably due to tuberculosis of the udder at	16·0	„ „ „
Possibly due to tuberculosis of the udder or to other sources of infection at	5·2	„ „ „

10. Although it is difficult to deny the possible danger of other sources of infection it is clear that tuberculous infection of the milk is in a very high proportion of the cases due to tuberculosis of the udder. It is also obvious that all cows in a state of advanced tuberculosis are potentially dangerous on account of their special liability to tuberculosis of the udder and of the infectiousness of their dejecta. Under the present conditions the proportion of tuberculous animals among cattle of more than four years is considerable.

11. These facts are of value from an administrative point of view, for since *the presence in our herds of a large number of tuberculous cows* is tolerated, it is important to have the means of discovering when these cows are actually, or potentially, dangerous to human health.

12. Tuberculosis of the udder can be detected with great accuracy by a combination of veterinary inspection of the cows and of bacteriological examination of the milk obtained from udders showing signs of disease, more specially enlargement and induration. It is unfortunately impossible for the most experienced veterinary surgeon to distinguish, by inspection and palpation, tuberculous mastitis from all other forms of mastitis. It is also practically impossible for the veterinary surgeon, unaided, to discover by ordinary inspection early tuberculous lesions of the udder.

The Manchester records show that out of 940* udders which veterinary surgeons of exceptional experience and ability thought might possibly be affected with tuberculosis, only 242 were proved by bacteriological examination actually to be tuberculous. In my opinion, the evidence recorded in this report shows that the bacteriological results, when obtained by suitable methods, are reliable. These results were controlled time after time by post-mortem examinations of condemned cows, and by the state of the mixed milk after the removal of condemned cows.

The accuracy needed for the purposes of public health administrative work can therefore be obtained only by a combination of skilful veterinary inspection and bacteriological examination.

13. In order to determine the farms requiring inspection it has been found necessary in administering the Manchester Milk Clauses to examine bacteriologically the mixed milk supplied by each farm. The bacteriological testing of mixed milk is, unfortunately, a slow process. Simple microscopical examination yields a certain proportion of trustworthy positive results, but negative results cannot be relied upon. The inoculation method, which gives much more accurate results, involves a delay of 10 to 20 days, and this delay appears to have been taken advantage of by some farmers, who, apparently being warned by the sampling of their milk, have removed suspicious cows from their farm before the visit of the veterinary inspector.

14. This defect, though a serious one, has not prevented the Sanitary Authority of Manchester from obtaining, by skilful administration, a considerable improvement in the milk supply. A reference to Table III. will show that while during the years 1896–1900, 16·8 per cent. of the farms supplying milk to the town were tuberculous, the number had fallen to 7·2 per cent. in 1907.

The fact that similar results have not been obtained in other towns, is I think due chiefly to lack of continuity in the work, probably in part due to financial reasons. The work done in Manchester has been of considerable magnitude ; it has been continued steadily for over 12 years and has involved a considerable amount of expenditure on the part of the town, and of labour on the part of the Medical Officer of Health, the Bacteriologist, and the Veterinary Surgeon.

15. Notwithstanding the measure of success obtained in Manchester in the course of 11 years, it is obvious that better results might have been obtained if diagnosis of tuberculosis of the udder, or the discovery of cows producing tuberculous milk could have been effected more rapidly. This appeared to me so important that I have considered carefully whether the bacteriological methods might not be improved. After many attempts I have not succeeded in finding a method of microscopical examination by which it would be possible to prove with certainty that *samples of mixed milk* collected at railway stations were entirely free from tubercle bacilli. On the other hand I have satisfied myself that, by taking certain precautions, *it is generally possible by the microscopical method to determine rapidly whether tubercle bacilli are present or not in the unmixed milk obtained direct from the cow.*

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* It is only fair to say that in some of these cases the suspicion was very slight, and that in a few other cases the samples of milk were taken for the purpose of gaining experience. I think, however, that I can say without fear of exaggeration that *not more than one-third* of the udders which on inspection appeared to be possibly affected with tuberculosis, were on bacteriological examination proved to be actually tuberculous.

On the basis of a somewhat limited experience I have come to the conclusion that it is possible by this means to detect tubercle bacilli in the unmixed milk of more than 90 per cent. of the cows that yield tuberculous milk capable of infecting guinea pigs.

The cases that would escape if this method was used could be detected by submitting the samples giving negative results to the usual inoculation test.

16. The chief objection that may be offered to this microscopical method is that, as there would be no preliminary testing of railway samples, *all the farms* would have to be inspected periodically, and this would require a greater staff of veterinary inspectors than is needed under the present system. This, however, apart from the cost, would be an advantage, for the results obtained would be better than those obtainable at present. (The examination of mixed milk would still have to be carried out from time to time for purposes of control.)

Primary inspection of the farms could not, however, be carried out without additional powers.

17. One of the facts brought out by the work done in Manchester, requires some consideration. Some farmers who supplied tuberculous milk to Manchester have, after this had been discovered, ceased sending their milk to the town, and now send it elsewhere or use it to make cheese. Occurrences of this kind indicate the necessity of strict control of the milk supply of *every district.*

18. So long as the presence of tuberculous cows, and more specially of aged tuberculous cows, is tolerated in our herds, a certain amount of tuberculous infection of the milk supply is inevitable. The elimination of cows with tuberculous udders undoubtedly removes the most material and dangerous source of infection, *but it is only after the milk has become infectious* that these cows are detected. *Frequent inspection* is therefore indicated under the present system of control.

19. Preventive methods based upon the state of the milk or of the udder cannot give results equal in value, either from an agricultural or from a public health point of view, to those that could be obtained by methods having for object the *eradication of bovine tuberculosis.* The latter, though more costly at first, would yield more permanent benefits, and finally be less onerous.*

20. Measures having for object the control of milk supplies, to be efficient must be carried out uninterruptedly year after year, very systematically and over fairly *extensive continuous areas.*

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* As this aspect of the question is not discussed in the report, I must refer the reader to a paper bearing upon it, in the "Transactions of the British Congress on Tuberculosis," State Section. Vol. II., pp. 235–282. London. 1902.